

Barba.
MISCELLANEOUS

DISSERTATIONS
ON
RURAL SUBJECTS.



L O N D O N,

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MDCCLXXV.

INTRODUCTION.

THE following Dissertations are upon subjects of importance in rural oeconomy. Some of them have been treated of by others in a general way, but there is much room for improvement. This will appear on perusal of the short list of these, viz. that relating to Fences. The several methods of fencing in different countries are described, of lands of various kinds and different situations. The two principal uses of fences are for shelter to lands, and to cattle that feed upon them; and as a security and



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and defence from damages. The first of these is chiefly attended to, in making common quickset-fences. Much wood is planted, and this undoubtedly produces shelter; but much wood is no security against damage, and is itself an injury to the land. A moderate quantity of wood properly disposed, answers both purposes of shelter and defence, and cheap methods are here laid down to attain both; which it is presumed will be acceptable to husbandmen, who are sensible of the benefit of good fences, and of the damage and continual expence of repairing those that are insufficient. To render this article the more generally useful, the best practical methods are described, of securing lands from floods, and encroachments of rivers or other contiguous waters: for by these great injury is done, and much land washed away, which might be prevented, if the

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the owners were acquainted with the means of doing it.

The next is a very extensive article. Manures are used by husbandmen universally. Without their aid, lands would sink greatly below their present value. Farms that are much deficient in manure are low rented; but where manures abound, the tenant has the means of improvement, and can afford to pay a good rent. He may, notwithstanding, use too much manure, or apply it improperly. Plants that are cultivated for their seed, as corn and pulse of all sorts, may be too highly manured: for a large quantity of manure promotes the growth of straw more than the grain; and this may be carried to such an excess, that the crops will be blighted, and no grain or very little produced. There is not the same danger in cultivating natural or arti-

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ificial grasses, not intended to stand for seed; yet even they may be over-done with manure, which will make them gross, rot at bottom, and lodge.

The qualities of manures, and in what manner they operate upon land, are points of enquiry that merit the attention of all cultivators of land; in these we are not much assisted by the common practice of farmers; who are not accurate in making experiments, and very rarely keep any register of them. The operations of bodies, and of manures in particular, are traced with much difficulty; and what has rendered them the more so, is the propensity to form hypotheses upon theories, unsupported by experiments. It has long been a current opinion, that nitre or other salts were the causes of fertility; and consequently, that those manures that
were

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were found to be the greatest enrichers of land, contained a large proportion of those salts: this was said of the several sorts of marle, lime, and others. But when it was discovered by experiments, that they contained no salts, it was then said that they attracted them from the air: but this also is now found to be an error; and therefore we must endeavour to account for the operation of manures, in such manner as is warranted by accurate experiments.

This is not a matter of mere theory: just principles lead to a right practice, as we shall see in the present case. This rendered it necessary to enter into a discussion of the nature and operation of some of the principal manures; among these marle is to be ranked, the nature and operation whereof has been long

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imperfectly understood ; and, though an excellent general manure, has to a proverb been excluded from strong land. Marles differ in their qualities, but farmers had no other way to judge of them, or to distinguish them from other earths, but by their external appearances, in which some other earths, pernicious to land, very much resemble them. To prevent the ill effects of such a mistake for the future, a method is here laid down to distinguish genuine marle with certainty, by a short and easy process, that the farmer may perform himself; and he is advised to do so, before he lays any earth supposed to be marle upon his land, whereof he knows not the effects from experience.

By this process we may go a step further, and not only distinguish marle from other earths of a like appearance,

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pearance, but also discover the composition of the several sorts of marle, and to what kind of land each of them is best adapted, for its improvement.

Chalk is much of the same nature as marle, particularly such as is soft, soapy, and unctuous ; yet chalk, till of late, has been esteemed a manure proper only for strong land, as marle was for light land. But chalk is now found to be a great improver of both sorts, light as well as strong.

The opinions concerning lime have been so various and contradictory, that many were deterred from using it : though the ill-consequences that have ensued a plentiful liming, seem not to have arisen from the lime, but from an injudicious management of the land afterwards, as may appear from this Dissertation ; wherein the reader will find several

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other points discussed relating to manures, tending to settle a just theory of their operation, and be of use to the practical husbandman.

The Dissertation on Drill-sowing relates principally to the new husbandry; though that manner of sowing is not limited wholly to hoed crops. The drill-plough is an excellent invention. A great deal of seed is saved by it, and by the regular planting in rows, hoes of various sorts are admitted to cleanse the intermediate spaces from weeds; and by stirring the earth, both the crop and land is improved. Mr. Tull's drill-plough is a very good one, and answers in practice what he has said of it. He constructed it to sow double rows upon narrow ridges, for the purpose of horse-hoeing; and his land being most of it light, and the drill drawn by a small horse along
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the tops of the ridges, he made it very light; and is indeed too slight to be used upon very strong land: but by a different construction, here described, that inconveniency is removed. Another great improvement is also described here, which is new, and never before made public. Mr. Tull's drill-plough was constructed to sow two and sometimes three rows, but to sow three the drill was too complicated. Some other drills have been invented since his, to sow two, three, and some four rows; I had one made to sow six rows at once, at the distance of six or seven inches. But in one particular all these instruments are defective; they sow the rows at certain stated distances, from which they cannot be altered. But, after various attempts to remedy this inconvenience, I at last succeeded; by which Mr. Tull's drill will now sow from
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one to six rows, at such distances exactly as the driller thinks proper. The contrivance to make it perform this, seems now so obvious, that it is surprising I did not discover it sooner; and confirms the observation in mechanics, that those of the simplest construction are the best, and of the most difficult invention.

I shall not here enumerate the several machines that have been invented for drilling, since Mr. Tull's drill-plough: but there is one that deserves particular notice, called the barrel-drill, which is an excellent instrument, first introduced by the celebrated Du Hamel. Imperfect indeed at first, but much improved by the ingenious Mr. Craik, and now made a perfect instrument. Upon Mr. Tull's construction three drill-ploughs are necessary to sow the different seeds used in the fields;
one

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one for horsebeans and very large pease; another for wheat, barley, oats, common pease, and other seeds of nearly the size of these; and a third to sow the smaller seeds, as those of turneps, cole-feed, carrots, &c. But one barrel drill sows all these; and a cheap method is described to make it deliver regularly the intended quantity of each per acre. Here is likewise shewn a method of constructing it, to sow few or many rows, at the required distances. As now improved, it is a strong and cheap instrument, easily managed; and of such a plain structure, that it may be made or repaired by workmen commonly employed in husbandry business: so that upon the whole it is such an instrument as the most ingenious cultivators have long wished for, but has never before been offered to the public: and as it answers so well in every respect, there is no room to doubt,

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doubt, but when generally known, it will come into more general use than any other of these instruments has hitherto done.

The next Dissertation is upon Water-works, a subject of extensive use. In very flat countries, as Holland, they have abundance of water; but that having no current, is of no use to them in their machinery, wherein they are obliged to make use of wind. Of windmills they have great numbers, and employ them in all manner of heavy work: for grinding corn, fulling, sawing, in manufactures of paper, oil, metals, and many others; but with regard to power and steadiness, water is far superior to wind. In Britain there is great conveniency of water, but we are often defective in the application of it. Much more business might be done with the same water,

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water, if applied in the best manner. To assist those who would erect such works, and the workmen employed to erect or repair them, is the intention of this Dissertation.

The mechanic arts have their foundation in geometry. But in forming rules for practice, many circumstances occur, that cannot be accounted for by theory alone, without experiments. Water raised to a head, and issuing through apertures made below, has in theory a certain velocity; and it has been supposed, as indeed it seemed probable, that the quantity issuing was constantly and directly proportional to the velocity; and upon that supposition, rules were laid down of the expence and impulse of water passing through these apertures. But it appears from experiments that the quantity is not to be determined from the velocity, and

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and that the calculations of its impulse, founded on that supposition, is erroneous: which is necessary to be attended to, in the construction of all machines to be worked by the force of water.

The construction of the bottom-work of mills, locks, sluices, &c. with proper materials, and in such manner as to prevent their decaying, and to secure them from blowing, are matters of no small importance in these works: and concerning these, the reader will find ere this such directions as may be relied on in practice.



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B

The manner of fencing low wet land.—Stone fences, different ways of making them.—The expence of making stone fences.—The best method of planting waste land with wood.—Estimate of the expence and profit of such plantations from experience.—Fencing with walls of chalk-stones.—The manner of building to make them durable.—Of fencing and improvements on the Yorkshire wolds.—Fencing with double stone walls and wood planted between them; the expence and advantage of fencing in that manner.—Of ditch and bank fencing with quicksets.—The plants most proper for quicksets.—The most approved methods of raising and planting quicksets.—And of training them to make strong and durable fences.—A new method of making cheap and secure fences.—Fencing with sets planted in single rows.—Of tree fences.—Furze fences, how to raise and manage them.—Of briar fences.—Bank fencing against rivers.—Several other methods of fencing against rivers.



OF FENCES.

THE first step to be taken in order to improve land to the greatest advantage, is to divide and fence it. Good fences are of themselves a considerable improvement. They are a shelter to the land and cattle, and secure the products of the land from damage both from cattle and from the inclemencies of the seasons. It is unnecessary to insist upon the advantages of inclosures and good fences, daily experience shews the general sense of their utility; and that open fields, upon being inclosed, immediately advance in value much beyond the expence of inclosing them.

There are various kinds of fences, which should be suited to the nature of

the land to be inclosed, and the materials for that purpose that the country affords.

For low, wet, or moist land, sunk fences or ditches are the most proper. In such moist, soft land, ditches are cut at a small expence, and answer a double purpose, they serve to divide the land, and to drain it. Ditches of six feet wide at top, a foot and a half or two feet wide at bottom, and five feet deep, will make secure fences, and prevent cattle from rambling. The soil dug out of the ditches should be laid on each side; and a row of aquatic plants set along one side, within five or six feet of the verge of the ditch, makes a good shelter, and furnishes a considerable quantity of valuable wood. The proper sets for this purpose are those of alder, willow, asp, abele, black and white poplar, and the white willow; most of these rise to a great height, with naked stems, and are most suitable to large
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large fields; but for smaller fields they may be pollarded, or headed down to within seven or eight feet of the ground, which will make them grow with large thick heads, and afford a good shelter to such fields. About nine or ten feet in length should be left undug at proper distances (except a small trench cut along the middle of each) for a communication to the water in the ditch. These solid parts serve as bridges for carriages and cattle, and should have a gate to each. The expence of dividing low ground in this manner is not much, and the improvement in the herbage, for feeding cattle, and hay, and the lop of the trees very valuable.

For wastes, commons, and dry lands that lie high, that abound with stones lying on the surface, or beds of stone at no great depth, the best and cheapest fences are stone walls. The ingenious author of the Complete English Farmer

objects, however, to these stone fences as follows :

“ In Gloucestershire and Worcestershire, where larger tracts of waste lands are now enclosing, fencing is there carried on in two very different methods, neither of which, in my opinion, is the most effectual or least expensive ; the first is, by digging stones, which in that part of the country every where abound, loading them in carts or wheel-barrows, and shooting them in lines, where they are afterwards erected into walls without cement, and extended for miles without any defence. This subjects them to many accidents, and it is no uncommon thing to see breaches in them of very considerable extent, by which means they cease to be a security, and are for ever wanting repairs.”

Upon this it may be observed, that walls without cement, or dry stone walls, are to be seen in many parts of Britain,
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that have stood well time immemorial; but to insure their duration the following precautions are necessary: 1. That they be not built too upright, but battering, so that they may be considerably narrower at top than at the foundation. 2. That the work be well bonded, by laying the long stones across the walls at small distances asunder: this is absolutely necessary, but in which the masons are very apt to be negligent if not strictly attended to, as every one must be sensible who has been concerned in such buildings. 3. All such walls should be coped at top, without which they will be of no long duration. And, 4. gates should be erected at proper distances, for huntsmen and travellers on foot to pass, without damaging the walls. These circumstances being duly attended to, there is no doubt but such stone walls will make excellent and durable fences; and it seems highly probable that a defect in some one or more

of these particulars, was the cause of the walls above mentioned having such breaches in them so soon after they were built.

The other method of fencing censured by the author is, “ by making a kind of gutter on each side, and throwing the earth up in the middle, which rises and forms a ridge about thirty inches high. About six inches above the base of this ridge they plant one row of quick, and about a foot above that they plant a second row, and over all, the loose earth from the gutters on each side, is thrown a-top, and thus their fence is completed. To defend the new planted quick, posts and rails are set up on one side, and a sort of clumsy slit gates are staked upon the other. To this method of fencing the quick, I have no other objection except the expence of it; but against the manner of planting the quick much may be urged. Quick loves a rich, moist, loamy soil,

soil, neither too wet nor too dry ; and as its roots never descend deep in search of nourishment, it feeds only on the rich pasture near the surface, and the richer and more enlarged that surface is, the better it thrives ; but by cutting a gutter on each side they narrow its bounds, and by forming the earth on which it is planted into a ridge, they make way for that moisture by which it is sustained to drain off ; so that though it may seem to thrive for a few years at first, it will certainly dwindle, and never arrive at its proper growth." In which opinion I cannot but concur with the author.

With regard to dry stone fences, Mr. Scroope, of Danby, near Richmond in Yorkshire, inclosed nine hundred acres of moor land. The surface of the moor, says Mr. Young, yielded " in some places a sufficiency of stones for this work ; but in many others pits were sunk for them ;
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the quarries are all lime-stone, and mostly near the surface. The first year two hundred and eighty-nine roods were built of the ring fence. This work was all contracted for by the measure, at 5s. 6d. per rood of seven yards long, and five feet high. A gate, two posts, and the irons, came to 6s."

And speaking of Mr. Danby's improvements of Swinton upon Moors, in the same county, he says, "The only method of inclosure used here is that of stone walls, and most excellent fences they are. The stones scattered over the land they loosen from the earth with wedges, and split them into small pieces; these they lay upon each other very artfully, building with them the walls, which are not only very strong, (lasting in full perfection beyond the memory of the oldest man) but have likewise a neat and good appearance. A small addition of the expence will cut them

them all into regular oblongs, which makes them look to the full as well as any the most regular brick walls.

“ The expence of cutting (in the common manner), leading, and building the walls six feet high, is 5s. 6d. per rood of seven yards running measure. The gateposts are of stone, and excellent ones; their cost scare any thing. A gate, irons, and posts cost 5s.”

Sir Digby Legard has given a still more particular account of these kind of fences on the wolds near Scarborough, and other matters relating thereto, which highly merit the attention of improvers of land in the like circumstances.

“ The estate, says this gentleman, where I have resided several years, consists of upwards of six thousand acres; and the uninclosed part of it, or what is called wolds, of five thousand acres, have never been let at more than a shilling per acre; and what I here say of a particular parish, is

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applicable to a very extensive country, twenty miles long and fifteen broad. The soil of the wolds is in general a light hazle mould, in some places intermixed with small stone, flint, or gravel. The depth of soil is from three inches to a foot, in general not less than five inches. Underneath there is a white lime-stone rock, by some called chalk, but I think improperly, it is more of the nature of marle. This stone rises often in large blocks, and is used in building, and for lime. It is hard, but not of a very durable nature, for if it be exposed to wet and frost it soon cracks and moulders away; but if the walls built with it are kept well covered, it will last for ages. After a time it encrusts with a moss, which preserves it."

He then proceeds to state the prices of labour, &c. in that country :

" The

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"The daily wages of a labourer l. s. d.
in summer is 1s. in winter - 0 0 10

A carpenter per day - - - 0 1 6

A mason per day - - - 0 1 8

The day's work of a team, consisting of four oxen, two horses, and one man and one boy - - - - 0 5 0

A ton of coals, including turn-pikes, &c. costs - - - 1 4 0

A chaldron, or 32 bushels of quick lime costs - - - 0 12 0

The same quantity burnt in one's own kiln, costs - - - 0 7 0

A lime-kiln built of brick, with two eyes, to hold 20 chaldrons - - - - 15 0 0

Walling farm-houses per rood, viz. seven yards, and one yard high - - - - 0 4 0

A rood of wall, including getting up stones, lime, and building - - - - 0 10 6

N. B.

N. B. Getting up is 5d. per load,
 leading as much; and four good
 loads will build a rood. l. s. d.

Rough stone walls for fences,
 built without mortar, per
 rood - - - 0 4 0

Plaistering the inside walls of
 farm-houses per yard - - 0 0 2

“As to wood for fuel and fencing, true
 it is that this country does not at present
 furnish it; but it is no less true that it is
 capable of furnishing enough for every
 æconomical purpose. The hedges and
 hedge-row trees round every village are
 a proof that the soil is not improper for
 wood; and some very thriving plantations
 on the tops of the hills, which a few gen-
 tlemen have had courage to raise, will be
 a lasting monument to their praise, as
 well as an example for others to imitate.
 Though the Scotch fir has been usually
 selected for these trials, and has succeed-
 ed, yet the ash will do as well, and is a
 much

much more valuable tree. For ploughs, fellies of wheels, and axles, for sheep bars, and for the cooper's use, no tree is equal to it : it is besides a very quick grower, and springs admirably from the old root. I confess that some plantations on the wolds have failed, but the failure has generally been occasioned by an insufficient fence, whereby the plants have been ruined by sheep, their greatest enemy, or they have not been planted thick enough at first : this is a common but a capital error. I find by experience that nothing is so essential to young plants as warmth ; it is more material than depth or goodness of soil. Trees grow quicker and larger in good than in bad land, but some kinds will grow in any soil : without shelter no trees can exist. Remove some rich earth from a valley to the top of a mountain, plant a single tree therein, and water it when necessary, no art will make it prosper. When trees are set very
close

close together, so as at first almost to touch each other, they not only afford warmth, breaking the force of winds, but supply constant moisture to the roots. The rain and dew is not so soon exhaled, and the stagnation of air occasioned by the shade furnishes that putrid heat and fermentation so necessary for the purposes of vegetation. The mellowing and enriching the ground by a crop of turneps, and all the leguminous tribe which afford most shade, evince the truth of this observation. Raising wood in a bleak and exposed country is not only a desirable object, as affording a supply for fencing, fuel, implements of husbandry, and for buildings, but has this additional excellence, that if the plantations are discreetly placed, and the inclosures properly bordered with wood, all the adjacent land is considerably benefited, by being protected from the rage of impetuous storms; the grass grows better, and the cattle thrive

thrive much more on account of the shelter.

“ Nor do I believe, that low-rented land, especially the sides of steep hills, can be turned to more advantage than by planting them. For instance, I have an inclosure of about six acres on the top of a high hill, which thirty years since was planted with Scotch fir, ash, and beech. The trees are now at a medium twenty-five feet high; each plant will make four rails, and is worth 1s. 6d. they stand at about six feet distance from each other; therefore the six acres contain seven thousand two hundred and sixty trees, valued at 544l. 10s. the fencing this plantation and repairs cost 30l. the plants, four years old, at 5s. per 100, cost 18l. the rent of the land before the inclosure was 1s. per acre: deducting then 50l. for expences, the product of six acres in thirty years is 494l. But the compound interest on 50l. at 4 per

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cent.

cent. will, in thirty years, amount to above 60l. and there still remains a clear profit of 430l.

“ As there may be some difficulty at first, to procure posts and rails for an extensive enclosure; and as even a post, a double rail and a bank, is hardly sufficient to turn a sheep, I would recommend it to those adventurers, who are about to inclose, and can afford to lay out a little money extraordinary on an excellent fence, to have recourse to the natural produce of the country, and make use of dry stone walls. I know that a strong prejudice prevails against these materials; that it will be urged that the stone is perishable; and that if this kind of fence was proper, it would long ago have come into general use, as the whole country abounds in stone. But let us not take opinions on trust, or fancy with the vulgar, that any thing is impracticable, only because it has not yet

yet been put in practice : the most obvious improvements have lain hid for ages.

“ I have been making experiments for some years past, on the durability of the white stone, and have built several fence walls with it, in the most exposed situations, which have hitherto withstood the weather perfectly. The only precaution I used, was to dig up the stone early in the spring, that it might have the whole summer to dry (it is naturally very damp and moist), and so be better able to resist the frosts of winter ; and to cover the walls with a projecting coping, either of whins or sods. This secures them from perpendicular rains : and though the sides are exposed to beating storms, the wind, which blows through, presently dries any moisture occasioned by the weather. Indeed I find, that the more open the walls are built, the less liable they are to perish. That part next the earth is in most danger ; and if it should be found

necessary, the lowest course may be laid with flint, with which the country abounds, and which is quite durable.

“ These fence walls are two feet thick at bottom and one at top; are four feet and a half high, exclusive of the coping; and seven yards in length costs about 6s. But the price must in a great measure depend upon the distance of leading from the quarry, and on the ease of getting up the stones. In stating the above price I suppose that the stone quarry is not above five or six hundred yards from the work; and that a good labourer can get up at least two loads in a day.

“ A bank with a post and double rail with us costs 3s. per rood, is hardly to be depended on, at first, as a fence against sheep, and is perpetually out of repair. But though I strongly recommend a trial of these stone fences, I would by no means exclude the planting of quick wood hedges; which afford the
best

best shelter, and are highly ornamental. A double fence at ten or a dozen yards distance, and the intermediate space planted thick with trees, hedges, and underwood, would be the most sightly, the most convenient, and the most profitable."

"I have inclosed three hundred acres on the top of the wolds, and have laid down the greatest part with various kinds of grasses.—I generally give the land three or four ploughings, and sow it in April or May, with grass seeds, with or without corn. The latter way usually succeeds best. I make my inclosures large, containing forty acres at least; by which means the fencing is less expensive. To inclose forty acres with a double fence, at 6s. per rood, will cost 150l. The preparation of the ground will cost 42l. For the ploughing an acre four times, and the seeds requisite, is worth a guinea. The interest of 190l. at 4 per cent. is 7l. 14s. but the annual advance

by the inclosure I have found to be at least 8s. per acre, consequently the advance on forty acres is 16l. or above 8 per cent. interest, on the money laid out.

“ But there are two things more to be taken into the account ; one is, that where a large inclosure takes place, the side of one close is a fence for the adjoining one, which reduces the expence half. The other, that a border of wood makes the double fence necessary ; and we have seen this amply repays the planter, at the end of thirty years. It is evident then, that the high wolds may, by inclosure, by the help of sheep fold, by cultivation, and a proper choice of grasses, be advanced 8s. per acre ; and that the capital employed will pay an interest of 8 per cent. This has been done. The three hundred acres were as bad as any in the lordship ; and the same improvement may extend to five thousand acres.”

Sir

Sir Digby's double wall fences are expensive; and, as he observes, are proper to be undertaken by those only who can afford to lay out money upon speculation and a prospect of being reimbursed in a long course of years; where this is no objection, the plantations in the intermediate space will very well repay the expence, even of the double walls. For the expence of building a rood, or seven yards in length of the double wall, is 12s. and the clear profit of the plantation, seven yards long and twelve broad in thirty years, amounts annually (in the proportion to his six acres) to 1l. 4s. 10d. an ample recompence for the money laid out.

Such plantations are very ornamental; and the excellent shelter they afford, when grown up, to the land and cattle, is a material consideration, in situations so much exposed to rough tempestuous weather.

But the most common fences are made with a bank and ditch, and the bank planted with two or more rows of quick-fets, of white or black-thorn, crab, holly, maple, withy, buck-thorn, and several others; which are often, but very injudiciously, planted promiscuously in the same hedge. The consequence of which is, that the larger plants over-grow the others, and so starve or stint them, that such hedges are of very unequal growth, and have many gaps in them.

But the greatest damage to such fences is done by the trees commonly planted in them; for these, by their shade and drip, and robbing the quick of its nourishment, never suffer it to grow to a good fence. Add to this, that next the bodies of large trees the hedge is generally broke down, and the gaps want continual repairing with dead wood. Upon the whole, there are no good fences where large trees abound in them; and when
planted

planted in the borders of small enclosures, are extremely prejudicial to the crops. Where timber or lop-wood are wanting, other places should be made choice of, to raise them ; for large trees are inconsistent with good quickset fences.

The plants most proper for quicksets are, the white or haw-thorn, the black-thorn, crab, and holly. The white-thorn is a pretty quick grower, when rightly planted in a proper soil. It is the most common, and makes a very good fence.

The black-thorn also makes a good fence ; not inferior to the white, if it likes the soil : but it is apt to spread its roots into the ground, and throw up many suckers, which makes it less esteemed than the white ; but the bushes of the black are the best and most lasting for stopping the gaps in hedges ; and it is not so liable as the white to be cropt by cattle.

Crabs

Crabs make a stout fence, if kept cut and trimmed to thicken it, otherwise they are apt to run up tall, with naked stems.

The holly is not so common as the others, because it is a very slow grower, but when well managed, and not planted too thick, makes a good fence; and being an evergreen, affords a very good shelter in winter, when the others are deprived of leaves.

Furze is easily raised upon banks of poor soils, grows quick, and makes a good fence in a short time.

The plants of the white-thorn are usually gathered in woods or coppices; but the poor, crooked, half-starved plants found there, are by no means to be depended upon, to make strong good hedges; but should be thriving plants, drawn out of a nursery, and may easily be raised by the farmer for his own use. For this purpose the haws should be gathered from young thriving trees, that
stand

stand single, and have the benefit of the sun and air round them; the fruit upon these are usually the soundest, and better ripened than those that grow in hedges, where the plants are much crowded. They should be gathered in November, when ripe, and in dry weather.

The haws will not grow the first year, though planted immediately, nor till the second spring after they are gathered; and must therefore be preserved till the proper time to plant them. This is done by digging a trench in a piece of dry ground, about eighteen inches deep, into which put the haws as soon as gathered; a thin layer of haws, and one of dry mould, alternately, to the depth of about a foot, and fill up the remaining six inches with mould; over which make a ridge of mould, and beat the sides of the ridge close with the back of the spade. This ridge will throw off the water, keep the haws dry, and secure them from frost.

Here

Here they are to remain near a year, viz. to the next October after they were gathered; and are then to be taken up and planted in the nursery, and in rows, for the conveniency of hoeing and weeding them. Some have directed them to be kept till the second spring after they were gathered, and then planted; but if delayed till then, many of them will have sprouted; and then if they are checked by rubbing off or wounding the sprouts, they will not grow. Other seeds that do not grow till the second year, may be preserved in the same manner, except such as are liable to be destroyed by vermin; for such should be put into earthen pans or jars, mixed with dry earth, the tops of the pans close covered with plain tiles or slates, buried in trenches, and the trenches covered with earth, in the same manner as the haws. They may likewise be preserved in boxes out of the ground; but the other way is the surest to preserve them sound.

Fences are often made with thin banks of unprepared earth, the face of the bank planted with two, sometimes three rows of quicksets gathered in the woods, and another row on the top of the bank: these very rarely make good fences; being planted so thick, the plants are weak, and rise in height with naked stems especially if not kept clean from weeds when young. It is common to see hedges run up to a considerable height, but naked and open at bottom. Cattle easily make their way through such hedges, and they are no security against hogs, nor against hares and rabbits. The goodness of quick fences does not so much consist in their height, as in their thickness, and being well furnished with strong branches near the ground.

The sloping sides of banks are improper to plant quicksets upon; for they throw off the rain water, and the plants are deprived of the moisture necessary

for their growth and nourishment. Thick banks and rich moist earth is an exception to this : but such earth is not common, in many places where such fences are necessary ; and in every soil, the following method of planting is greatly preferable.

First mark out the foundation of the bank four feet broad, dig it a spade deep or plough it. The ploughing or digging is to be continued from the foot of the bank twelve feet broad into the field on each side. The digging is to be deepest next the bank and gradually shallower towards the field, as in Pl. I. fig. 1. where a, c, d, b , is a section of the bank, and b, f, e , are sections of the ploughed ground on each side of the bank ; $a b$ is the bottom of the bank four feet thick, $c d$ is the top of the bank two feet thick, and $r s$ is the perpendicular height of it four feet. The ground on each side of the bank, is to be of such breadth, that
the

Fig. 2.

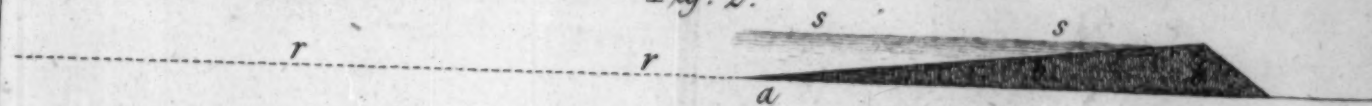
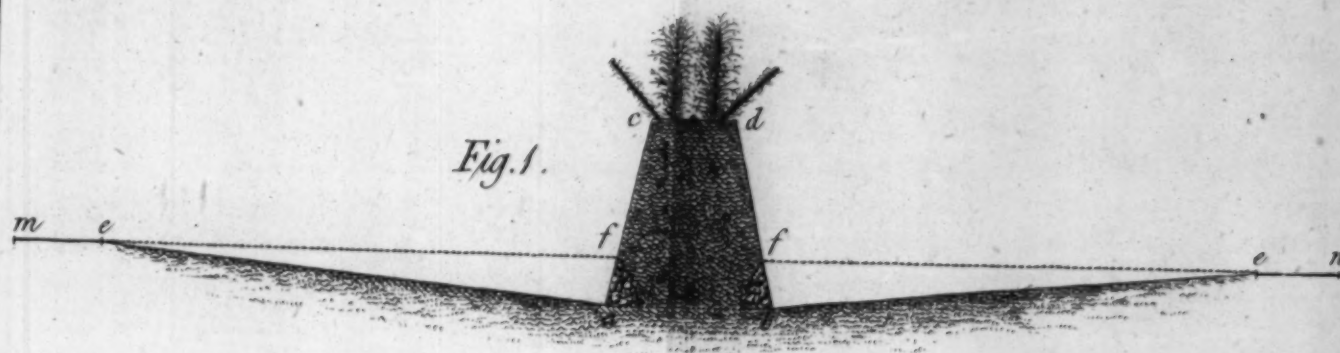


Fig. 1.



J. Lodge sculp.

the earth dug up there may serve to make up the bank to the intended height and thickness. As in the present case the area s , of the two sections of dug or ploughed earth a, f, e , and b, f, e , amount to twelve square feet, and the area of the section of the bank a, c, d, b , is also twelve feet, and therefore the earth dug up is just sufficient to make up the bank.

The foundation of the bank is made with turf laid length-ways, and joining to the lines made to mark out the foundation, and the intermediate space filled with earth, beat down close and level with the turfs. The next layer should be of turf, laid across the first, and of such a length that their ends may meet in the middle within a foot; and at every six or seven feet distance, the turfs laid across should be long enough to reach the whole breadth of the bank, and these serve to bind the whole together. The intermediate

mediate space in the middle being filled up and beat level with the turf and earth as the first, make then two more layers as before, and proceed in the same manner, until the bank is raised to the intended height. As the work is carrying up, the outsides of the bank should be beat close and smooth, and this repeated afterwards when they are moist with rain, which will close the seams, and unite the whole into one solid body. The middle of the bank should be filled with good mould, especially towards the top, where the fibrous roots of the setts will be most numerous. The top of the bank should be two feet broad, filled with the best mould, and levelled.

The best time to raise these banks is early in the spring ; the grass will form a swarth on the sides of the bank in summer, which being beat close and smooth when they are moist, will effectually consolidate them : and such banks well made

at

first, will last many years, and want very little or no repairing.

It is customary to transplant quicksets in the spring; but if dry weather succeeds, many of them are killed, or so much weakened that they never recover: nor are slight showers of rain sufficient to keep them moist, because they are planted upon sloping banks. The best time to transplant these sets is in October; for though they do not grow in winter, they are preparing to throw out new roots and buds early in the spring, and proceed in their growth without any check, which those transplanted in spring are always liable to.

Fences made in this manner, are in every respect preferable to those commonly made with sloping banks; with this further advantage, that these do not require ditches to carry off the rain water. The ground on both sides being dug shelving towards the foot of the bank,

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serves

serves to carry off the water ; and as the ground is dry again in a short time, cattle may lie close to the bank, which makes a very good shelter for them. Nor is any ground lost ; the sloping sides being sown with white Dutch clover seed, is a pasture for the cattle ; and so is the sides of the bank, that produce some grass, to which the cattle can reach to feed upon them. The dimensions of the banks here laid down, are sufficient for any common inside fences. But for outside fences or much exposed places, the banks may be somewhat thicker and higher and the quicksets having more mould to spread their roots in, will grow the more vigorously.—When these fences are made in declining grounds, that lie shelving towards one side of the bank, the rain water that runs from the field, together with what runs that way from the slope dug up to make the bank, may accumulate to such a body of water, as may wear away
away

away the foot of the bank. In such situation the foot of the bank may be defended by stones laid under the foundation, as at *f*, *b*, Pl. I. fig. 1. Or if that is not sufficient make a small ditch near *b*.

As the bank should be made in the spring, and the sets not transplanted until autumn, the mould at the top of the bank should in the mean time be repeatedly well dug or hoed, which will be a summer fallowing to it, will keep the earth mellow and open, and cleanse it from weeds more effectually than can be done after the quick is planted.

The setts should not be transplanted from the nursery until they are at least half an inch thick : their tap-roots when taken up, should be shortened to seven or eight inches, the fibres trimmed, and the tops of the sets cut off to within two inches of the crown of their roots, and immediately transplanted upon the banks in a double row, each row six inches di-

stant from the verge of the bank, which will leave a space of a foot wide in the middle between the rows; the plants at four inches distance in the rows. They should be planted when the earth is moist or an appearance of rain, with a trowel, which is a much better way than with a dibble.

Next summer the ground should be kept clean from weeds, and if hoed between the rows the plants will thrive the better. In October cut down the shoots produced in summer to within six inches of the ground, and cut the side branches within two inches of the stems. This cutting will thicken the sets at bottom and no more cutting will be necessary, but to trim up the sides every autumn with a sharp hook. The strong leading shoots that overtop the rest should also be shortened, and the hedge cut at top when risen to about three feet and a half high; for then the bank and hedge together will

will be between seven and eight feet high, which will be a defence against any cattle, or deer.

To prevent cattle from cropping the young quicksets, stakes of two feet and a half long should be driven near a foot deep into the top of the bank, next the edges on each side, and leaning outwards. Into these stakes work in bushes of the black or white-thorn, or strong furze, with the brush outwards; which will secure the quick until it is grown up and out of danger. By this method an immediate fence is made, and when the quick is grown up, is much superior to the common fences, and advances to maturity in a shorter time.

The usual method of raising quick hedges is from sets; yet it is still a better way to raise them from the seed, which may be very conveniently done upon these banks. As, instead of taking the setts from a nursery, the haws are sown

directly from the trenches in which they were laid the first winter, into the ground where they are to remain. Sow them in two drills on the top of the bank, in October, at the same distance as the sets; but much thicker in the drills, or not above an inch apart. They will come up the same as in the nursery, and are to be kept clean in the same manner by hoeing and weeding. When they are come up, it may be seen in summer which are the most thriving and strongest plants; these are to remain, and the weak ones are to be drawn up carefully in October, leaving the others at about four inches distance in the rows. The remaining strong plants may afterwards be managed as directed for the setts. In this method there is no time lost, but, on the contrary, the plants from seed, having long tap-roots, and a greater depth of mould to grow in than those in the nursery, and not being checked by transplant-

plantation, will make a quicker progress, and become stronger plants than they. For it is found by experience, that plants raised from seed, will outgrow the transplanted setts, when both are equally cultivated in every other respect, and in the same ground. It has indeed been said, that transplanted lucern grows more vigorously than the seedling plants, when both are cultivated alike, and in the same soil; but it is to be observed, that in the experiments made upon this plant, the transplanted lucern was always allowed most room: for though the rows of both were at the same distance, yet the plants were not so in the rows; the transplanted being set at six inches distance, or more, in the rows, but the others were sown thick in them by hand: so that in this respect, there was no just comparison. As two rows of quick-setts make better fences than three or four, it may be worthwhile to enquire, whe-

ther a single row may not do as well, or better than a double one. By some experiments made with several quicksets, particularly with crabs, I have some ground to think that very good fences may be made with a single row. It is observable in old hedges, where the plants of black or white-thorn have been cut down, there arises from the stumps, such a number of shoots, so strong and full of long sharp spines, that no cattle will attempt to get through them; being much stouter than the common shoots in the same hedge. This is occasioned from the numerous roots of such plants, which furnish the young shoots with a larger proportion of nourishment: and the same is observed in fruit trees when much pruned, they grow more luxuriant, and produce more wood, than they did before. By the amputation of their branches, their roots bear a larger proportion to their heads, and furnish them
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with a larger supply of the vegetable aliment. Upon this proportion depends the thriving of plants in general: and as the growth and vigour of the roots of a single row, can be more encouraged and promoted by cultivation, than those of many rows crowded together; the vigour of the single plants will be in proportion.

The goodness of such single fences does not consist so much in their lateral branches, as in the stems of the plants: for when they stand pretty close in a line, they form a strong fence. Thus the stem of a plant of the white or black-thorn in a thick hedge, is eight or nine years in gaining an inch in diameter; which may be seen by cutting their stems across, and observing the number of rings or circles, in them: each circle is a year's growth. But standing single, and well nourished, will gain as much in little more than half that time; and there-

therefore in a single row, set at the distance of six inches, the stems will approach so near to each other in a few years, that no cattle can pass between them; especially if strengthened and held together, by working some rods in between them.

But the strongest fences of all, and impregnable, may be made with plants of larger growth than the thorns or crabs, planted near each other in a single line, upon such a bank as is above described. All trees that rise with straight stems are fit for this purpose, the elm particularly, the beech, and hornbeam. Elms are remarkable for growing well in consort; and may be frequently seen growing in hedges thirty or forty feet high, and so close that their trunks almost touch one another. No cattle are able to penetrate a line of these trees so planted.

It is not, however, necessary that they should rise to such a height for a fence.

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But if topped at the height of ten or fifteen feet, and the branches kept cut on the two opposite sides, they make one of the most secure and durable fences imaginable, and afford an excellent shelter, without injury to the products of the fields surrounded by them.

The horn-beam may be raised from setts, or seeds, and trained in the same manner, and has one advantage above the others, that it usually retains its leaves in winter, and makes a warm shelter then to grafs and cattle.

Furze makes a good fence in poor land, where few other plants will thrive. The usual way of raising it, is on the tops of the banks, from seed sown in autumn, or early in the spring, in one or two rows. But in this way it rises too thick, and the plants so crowded, that they are much weakened; and as they root shallow, are very subject to die in patches, and the hedge is of little service. The best way

way of raising them is on the top of such a bank as above described; the seed sown very thin, in two rows, as common quicksets, the rows at a foot distance in the middle of the banks, and six inches from the verges on each side. When they are about half grown, cut down in October one of the rows almost close to the ground, which will soon spring up again; and as soon as this has advanced about half way, cut down the other row in like manner. By proceeding thus to cut the rows alternately, the bank will never be left quite bare; and by cutting them down before they are grown old, they readily produce new shoots. The neglect of this is the principal cause that furze hedges are so apt to die when cut. The furz most proper for these hedges, is the sort called French furze, being of a larger growth than the common sort.

There is, however, one inconveniency that commonly attends furze hedges; they
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are apt to produce considerable quantities of seed, which being blown about by the wind, or carried thither by birds, fill the contiguous lands with young furze; and this being repeated every year, it is troublesome and expensive to keep the land clear of them. This may in a great measure be prevented, by trimming the side branches with a hook, which will make them grow thick and close, and obstruct their blossoming: and many of the branches that would produce seed are cut away. For these reasons the round furze bushes upon commons produce none. They are continually cropt by cattle and sheep, and grow so thick and close, that the sun and air have not free access to encourage their blossoming and production of seed.

There are some soils so poor, that they cannot be fenced with quicksets: for scarce any plants fit for that purpose will thrive in them. There is a remarkable

instance of this in a letter to the Edinburgh Society; the author whereof says he had been twenty years a farmer in England, and when the letter was wrote he lived and occupied land in Scotland, which he attempted to inclose with quickset hedges, but without success. The land was so light and sandy that he could not make banks sufficient, and his cattle eat or trod down every kind of fences he attempted to raise.

At last observing, that none of the cattle touched the briar or eglantine plant, that grew naturally upon his land, he determined to try it for a fence; and for that purpose gathered a quantity of the hips in Autumn, kept them in sand during the winter, and in spring rubbed out the seed and sowed them in drills upon his low banks; they shot up to such a considerable height, that the second summer they made a good fence, few of his cattle venturing to break through it.

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Sometimes, he says, his sheep attempted it, but were so entangled in the prickly bushes that they could not extricate themselves, and would have died there if he had not cut them out. The letter was wrote some years after he had raised these fences, which, he says, continued still to thrive and grow vigorously; and thus he obtained good fences at a very cheap rate.

Another plant, that, if rightly managed, would make make good fences, is the bramble. In good moist land it makes long vigorous shoots in a season, and upon banks where it gets footing, it over-runs most other plants, grows so thick, and entangled together, that no cattle, or even hogs, are able to make their way through it. It will grow from seed or layers, and if raised on the top of a good bank, this despised plant would without doubt make a strong fence in a short time. It naturally trails upon the
ground;

ground; but if worked into stakes driven into the bank, a strong espalier fence might be made with it, a yard or more in height. As lands of different sorts and situations, require different methods of fencing, and in others a variety of them, I have been the more particular, that every person may make choice of such as he thinks will be most proper for his situation: without good fences no farmer can make the most advantage of his land; but will be liable to continual expence to keep his fences in repair, and to receive much damage in his crops from the neighbouring cattle, and his own; and therefore he will find his account in making his fences strong and substantial at first, and never suffer them to run to decay, for want of necessary reparation.

Lands that lie contiguous to rivers, and large pieces of water, and are subject to be overflowed by them, require to be
fenced

fenced in a manner different from any hitherto mentioned, by banks of earth, of a height and thickness, proportioned to the rise and motion of the water.

Still water does not much wear the banks, as of ponds and other stagnated water, where the banks, though steep, last a considerable time without much repairing, especially such as consist of strong tenacious earth. But the banks of rivers that have a quick current, of tide rivers, and wherever the water has any considerable motion, are there continually wore down and washed away by the agitation of the water.

The current of rivers is usually quickest at the surface, and for that reason the banks would be first worn away at or near their tops; and this happens where they have no covering to defend them; but in meadows where the banks are covered with grass, the roots of the grass are interwoven and matted so closely,

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that they bind and hold together the top mould, which the current cannot so easily loosen as the lower part of the bank, that lies exposed to the water, and has no roots of grass to secure it. Hence it is that such banks are worn away hollow below the turf, till the upper part, thus deprived of its support, becomes top-heavy, breaks off from the land, and falls into the river.

In this manner the steep banks of rivers are washed down ; as those of the Severn, where sometimes a great part of an acre of the land, breaks down at once, and is washed away. This always happens at an elbow or bending of the river, which is continually gaining there upon the land and retiring from the opposite side.

The banks made against a river, to secure the contiguous lands from being overflowed by it, should be raised higher by a foot and a half, than the river is ever known to rise to, in the greatest floods, after allowing for the settling of
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the earth whereof the banks are made, which is greatest in soft loamy soils. These banks should by no means be made like a wall, with a perpendicular or upright side facing the river; for such upright banks, are, for the reasons already mentioned, no durable security against running water. But the banks should be made sloping from the highest part down towards the river; and the more gently they slope, the less liable they are to be worn away by the stream, or motion of the water.

Pl. I. fig. 2. is the section of a bank made against the river *rr*, gradually higher from *a* to *bb*, where it is raised above the highest flood *ss*, and being made of good earth, and covered with turf, well beat down to close the seams, will perfectly secure the adjoining lands from being overflowed; and if well performed, will last for a long time. No general rule can be laid down for the exact slope of these

banks, nor is a small variation of consequence, provided the earth they are made of, and the turf with which they are covered, are of good earth.

But where the banks are considerably higher than the common surface of the water, though these banks will prevent the floods from extending further upon the land, they cannot stop the washing and wearing away the earth of the upright banks next the river, but they will, without some further security, be continually subject to wash down, become hollow, and wear away. To defend them with wharfing of stone or timber only, for the purpose of saving some land, would be attended with an expence that the value of the land saved is not sufficient to repay; unless where such wharfing is necessary to secure houses, or other buildings; or to make a convenient key for loading or landing of goods.

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The cheapest method for this purpose, is by such fences as the Dutch make, to secure their dams from the sea. They are made in the water, near and parallel to the banks; and though not strong enough of themselves to defend the banks, yet being supported on both sides by the water, the force of its motion is so much weakened, by the resistance of the water on the inside of the fences, that it is very gentle there; and the banks are then wore but little more than the banks of a pond, or other standing water.

These inside fences are made by driving a row of stakes or piles in the river, parallel to the bank, and near together, to stand as high as the surface of the water, and into these stakes are to be worked bushes of black or white-thorn, or furze, which are very proper for this use, with the brush pointing towards the river. This hedge being supported by the wa-

ter between it and the bank, resists and stagnates the current or tide in the river, and is by that means a great security to the bank.

Another method that some take to secure banks from the washing of the water, is by small wings or jettées of timber projecting from the bank a little way into the river. These check the current of the water from one wing to the other, and answer the end very well while they last; but the check given to the stream causes an eddy between the wings, and as the water rises a little there, and, by its weight and motion, wears away the earth at the sides and bottom of the wings, the timber work is thereby loosened, and then carried away by the current.

When there is plenty of stones or large chalk at hand, and the owner is willing to be at the expence of it, such banks may be effectually secured by throwing in the stones or chalk close to the bank, and
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laid shelving from the surface of the water next the bank to some distance into the river. The longer the slope is made, the more secure it will be, and the less liable to be carried away by the stream. And in order to secure it from being carried away or removed, rows of piles should first be drove into the bed of the river, across the stone-work, the heads of them to stand as high as the surface of the water next the bank, and gradually lower, the further they extend into the river, so as to answer the slope of the stones or chalk, above which it is not necessary they should rise.

The slope, or shelving of the surface of this work, may be determined by extending it into the river to twice the distance of the depth of water. Thus suppose the water is six feet deep at the bank, the stone work should extend from thence twelve feet into the river, sloping all the way. If it is carried out further it will lie the more secure, but should

not be of a less extent, unless the stones are very large.

The piles should be driven before any stones are thrown in, in rows three or four yards distant, and at such distance in the rows that the large stones cannot pass between them. Piles of oak are strongest, but fir piles are also very proper: for if they are of sound timber at first, they will never decay, as they are constantly under water: nor can they be wore away by the stream, being on all sides defended from it by the stones. Large stones should be thrown in at top, and smaller between; and the gravel and sand brought down by the current will fill up the cavities, so that the whole will in a short time become a close solid body, and effectually guard the bank from any wearing by the motion or current of the water. In this manner I secured the bank of a rapid river, about nine feet deep, above twelve years ago, and the work
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lies firm, notwithstanding the rapidity of the stream that continually washes it, and frequent high floods to which the river is subject.

Admitting the depth of the water to be ten feet, and the work to extend twenty feet into the river, these two lines being two sides of a triangle, right angled at the bottom of the bank, will determine the quantity of stone work, the section of which, in this case, will be a hundred square feet in the area, and every foot forward will require one hundred cubical feet of stone work, or about three cart loads; and thus the expence is easily computed, according to the distance from which the stone is to be brought.

MIS-

MISCELLANEOUS

DISSERTATIONS

ON

RURAL SUBJECTS.

The several kinds of manures used in husbandry.—Of the operation of manures upon land; and the different things relative thereto considered.—Of the principal single manures, marle, chalk, lime, and limestone-gravel.—A ready method of distinguishing marle from other kinds of earth.—Of the composition of marles, and what soils each sort is most proper for.—A pernicious sort of clay resembling marle, and how to distinguish it.—That marle does not attract salts from the air.—The methods of searching for marles, and other fossil manures.—Chalk beneficial to both strong and light lands. The manner of its operating on both.—Lime by some supposed to be an impoverisher of land. The ground and error of that opinion.—Several ways of burning stone and chalk into lime.—The best construction of a lime-kiln.—Of soap-boiler's ashes; the different sorts of them.—Of sheep's dung, and folding.—Of composts, and the best way of mixing them.—Of powdered manures; and foul salt.—Of new composts, recommended by Dr. Hunter of York.—Of liquid manures.

OF MANURES.

THE use of manures is to enrich land, or to correct its too great stiffness, looseness, or other natural imperfections.

Many different substances are made use of for these purposes ; and it is found by experience, that most kinds of matter, which ferment, corrupt, or fall into powder in the soil, are improvers of it.

Manures are commonly divided into three classes, viz. vegetable, animal, and fossil.

Vegetable manures are whole plants, or parts of them, ploughed into the land, while in a growing state, and in full sap ; as clover, pease, vetches, buck-wheat,

62 OF MANURES.

wheat, sea-weeds, &c. and the several parts of plants, their roots, branches, leaves, bark, and seed. Also saw-duft, malt-duft, peat-ashes, wood-ashes, and foot, rape-duft, kelp, and vegetable salts and oils, &c.

Animal manures are the several parts of animals, their flesh, fat, blood, inwards, hair, bones, horns, hoofs; and the dung and urine of animals, horses, black cattle, sheep, hogs, pigeons, poultry, rabbits, human ordure and urine, woollen rags, &c.

Fossil manures, are several kinds of earth, clay, sand, chalk, marle, shells, lime, limestone-gravel, common salt, &c. All these, and mixtures of them, as soap-boiler's ashes, tanner's-bark, lime rubbish, &c. are found useful for improving and enriching of land.

Rich loams consist of a due proportion of clay or strong earth, and sand. They are of a crumbly, mellow, flexible nature,

and easily tilled: they are not subject to the imperfections of other soils, to cake, burn, or parch, with drought or heat; nor to poach after rain: but constantly retain a degree of moisture sufficient for vegetation; but not so much as to obstruct the plough, or stick to the shoes in walking over them immediately after rain. Such soils, being naturally fertile, require little or no manure, or superinductions of any kind; but may, with proper tillage and cropping, be kept in a continued state of fertility.

Most sorts of land that deviate from the constitution of the rich loams, may be brought to resemble them by mixtures of other earths. Clays, and very strong lands, are brought into a proper temper by laying on them a due quantity of sandy light earth; and light lands, by laying on clay and strong earth. These are lasting improvements, but they are attended with great expence. The digging

ging, carrying, spreading, mixing, and incorporating large quantities of those earths with the land, are too chargeable for common farmers to perform extensively; for which reason they must have recourse to manures and tillage, to restore the fertility of their lands, exhausted by repeated crops. In what manner the different manures operate to produce this effect, is next to be considered.

It is a general property of manures, to ferment in the soils with which they are mixed. The fermentation excites an intestine motion in the soil, divides and separates the part of it; which is apparent from its swelling and crumbling: the fermentation does not however make any addition to the vegetable food of the soil; for that remains the same, whether it is divided into many or few parts: but a minute division is an excellent preparation of the soil, to receive a new supply of the vegetable food from the atmosphere,

sphere, which is stored with all the variety of matter necessary for the nourishment of plants. Fermentation therefore opens the soil, and multiplies the pores of it: the air, dews, and rain, find an easy entrance into these pores, and deposit there the nutritious particles; and at the same time render the soil pervious to the tender fibrous roots, into the pores of which they extend, and thence collect their nourishment.

The vegetable food enters but a little way into the land, unless it is opened by tillage or manure; the richest soils are so only near the surface; if dug or ploughed deeper than usual, though the deeper earth is naturally as good as the surface, yet it will not produce so good crops, till it is opened by tillage or manure; and also exposed for some time to the influences of the atmosphere, and receives from thence the vegetable food. This is a fact generally known to husbandmen.

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Land

Land of a deep staple, that has been ploughed deeper than usual, requires more than the usual quantity of manure to keep up its fertility. If tilled to the depth of eight inches, it will require more manure to enrich so large a quantity of earth, than it did when tilled but to six inches deep; but this additional expence will be overpaid by an encrease in the crops.

Fermentation is one of the principal means whereby the earth is enriched, and is not the effect of manures only, but is excited in some degree, by every change in the temperature of the air; by heat, cold, dryness, or moisture, the particles of the soil are put in motion, divided, and new pores or cavities opened, into which the nutritious aliment is deposited from the atmosphere. Without such a continual supply, the earth would soon be reduced to a state of barrenness; as the plants that grow upon it are
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constantly draining it of the vegetable food.

But though manures act principally by fermentation, they may, and probably do, operate in other different ways upon the soil, whereof no certain account can be given, as we are not furnished with experiments necessary to determine them, for notwithstanding the general use of manures, the practice of farmers in that respect, and their observations upon their effects, are by no means sufficiently accurate to establish any just theory. Yet, of such importance to agriculture is the knowledge of manures, their natures, and manner of operation, that an enquiry into them, so far as we have facts to proceed upon, cannot here be wholly omitted. We shall therefore consider what some of the most ingenious modern authors have said upon this subject, and take notice how far their theories appear to be well founded, or seem defective.

68 OF MANURES.

Not however with an intention of determining positively upon this abstruse subject, but in some measure to pave the way for future experiments.

The principal difficulties in relation to the operation of manures, are concerning the vegetable and animal kinds, which, if they could be clearly determined, would in a great measure determine the rest. That they all excite a fermentation in the soil, as above described, is generally admitted; the difficulty lies in determining whether they have any other considerable effect, and enrich it by furnishing the pabulum, or food, by which the plants that grow therein are fed and nourished.

When land is manured with vegetables, or with the parts, or dung of animals, they ferment and putrify therein, and by the putrefaction they are dissolved, and reduced to their first principles. These manures are found to be
great

great fertilizers of land, and as their principles are supposed to be of the same nature with those of the plants that grow upon the land, and that they are much nourished, and encrease in growth, by the application of these manures, it is concluded that the plants are fed and nourished by the dissolved principles of the manure; and that the salts and oils of the putrified manures, are absorbed by the roots of the growing plants, and assimilated to their salts and oils.

This appears to be a probable theory, and in confirmation of it, it is found, that many roots of plants cultivated in kitchen gardens, that have been much dunged; are tainted by the dung, and have a rank taste: and M. Duhamel gives an instance of the seed being also so much tainted by human ordure, that horses refused the oats that grew upon a field manured with it.

There are however some material objections to this opinion of the operation of these manures, which shall be taken notice of, after reciting the opinion more particularly, as stated by some of the ingenious supporters of it.

“ Manures, says Mr. Dickson, operate in all the different ways by which vegetation is promoted: they operate by communicating to the soil, with which they are mixed, the vegetable food which they contain—by communicating to it a power of attracting this food in greater plenty from the air—by enlarging the vegetable pasture which it contains—and by dissolving the vegetable food, which it is already possessed of, and fitting it for entering the roots of plants.—If the qualities of dung are considered, it will appear, that it promotes vegetation in all the different methods mentioned.

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“ While bodies are in a sound state, their parts adhere firmly together, and they are incapable of being turned into the parts of other bodies. To render them capable of this, they must be reduced to their first principles. This is done by corruption. It is observed, that by corruption, all the parts of bodies are relaxed, and the salts, oils, and other juices which they contain, from being fixed, are made volatile.”

“ It is, says Dr. Hunter, of great moment, to fix upon what is really the nutriment of vegetables, as it will enable us to conduct our compost dunghills upon just and rational principles. The doctrine of manures is but little understood. The farmer should at all times retain in his memory a general idea of them. He may divide the manures into four kinds.

“ 1. Such as give nourishment only, as rape-dust, foot, malt-dust, oil-com-

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post, blood-compost, pigeon's-dung, and all hand-dressings.

“ 2. Such as give nourishment, and add to the soil; as horse-dung, cow-dung, human ordure, rotten animal and vegetable substances.

“ 3. Such as open the soil, and do not nourish in their own nature; as lime, light marles, sand, and vegetable ashes.

“ 4. Such as stiffen the soil, and at the same time nourish a little; as clay, clay-marles, and earth.

“ We cannot pay too much attention to every thing that relates to manures; without their assistance, the richest soils would soon be reduced, by frequent cropping, to a barren state. It is pleasing to observe, how the dissolution of one body is necessary for the life and increase of another. All nature is in motion. In consequence of the putrid fermentation that is every where carried on, a quantity

tity of vegetable nutriment ascends into the atmosphere. Summer showers return much of it again; but part falls into the sea, and is lost."

"Were vegetables, says Dr. Home, to be destroyed, only by external force, by far the greatest part of them would remain untouched, and so be an useless burthen on nature. Were they to be destroyed by an internal fermentation, as at present, without having their parts volatilized; the particles to which they must be reduced, would be continually washed off from the soil, carried into the sea, and so be of little use towards the nourishment of other plants.

"The only proper and wise scheme is followed, the oils and salts, from being fixed, are volatilized, and carried up into the air, and descend again to fructify the earth."

There is no doubt that the salts and oils of vegetable and animal manures,

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are volatilized by a putrid fermentation; and it is the common opinion that they are thus fitted to enter the roots of plants for their nourishment: but if they are carried up into the air, and the earth is not fructified by them, till they descend again; of what benefit will this be to the field upon which these manures were laid? The farmer will have little reason to expect the return of these volatile particles, to the spot from whence they ascended; but on the contrary, he may be almost certain, from their volatility and extreme lightness, that they will be divided and scattered in the atmosphere to a great distance; and though by an alteration in the temperature of the air, they do descend again upon the earth, with the dews and rain; unless they fall upon his land, and upon that particular spot he had manured with labour and expence, they will be of no advantage to him.

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This opinion, however, of the earth being fertilized from the atmosphere, agrees with Mr. Tull's theory, which is the most unexceptionable theory of vegetation, that has been offered to the public. Yet, I know not how it has happened, that it has by several ingenious persons been misunderstood, and by the above quoted authors in particular. And as this is a matter of importance, I hope the reader will excuse a digression, in order to explain it.

Mr. Dickson, says, that " Mr. Tull has endeavoured to prove, that earth is the food of plants, and hence infers, that to divide the earth into minute particles, by which it is fitted for entering their roots, is all that is necessary in agriculture; and this he asserts may be done by tillage, without manure. But it is abundantly evident, that other principles, besides earth, are in the composition of this food; and if this is true, the want
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of manures, which provide these other principles, cannot be supplied by tillage. Supposing we allow, with Mr. Tull, that earth is the food of plants, yet still it does not follow, that tillage may supply the place of manures. It is certain that every particle of earth which we observe, is not of the kind that is the food of plants. Every soil is a composition of different earths, several of which, it is obvious, are not of this kind."

"The ingenious Mr. Tull, and others, says Dr. Hunter, have contended for earth being the food of plants. If so, all soils, equally tilled, would prove equally prolific. The increased fertility of a well pulverised soil, induced him to imagine, that the plough could so minutely divide the particles of earth, as to fit them for entering into the roots of plants."

That these gentlemen have mistaken the theory, may appear from the following observations.

I. Mr.

1. Mr. Tull, says, that manure is not necessary in the new, or horse-hoeing husbandry, particularly for corn: which he proved by his own practice; and has since been fully confirmed by the experience of other ingenious cultivators. But he does not deny the benefit of manure in the common husbandry, but asserts the necessity of it. Thus, p. 19, he says, "A considerable quantity of dung is so necessary to most corn-fields, that without it, little good can be done by the old husbandry, &c." See also, p. 211, 261, and several other places, to the same purpose.

2. He supposes that earth is the food of plants, but does not exclude other principles: for in treating on this point, he says, p. 14, "And earth is so surely the food of all plants, that, *with the proper share of the other elements*, which each species of plants requires, I do not find but that any common earth will nourish

rish any plant." He thought that earth was the vegetable food principally, as being the most solid and fixed principle of plants, but he does not therefore exclude the rest, any more than Dr. Home, who supposes nitre is that food; or Dr. Hunter, who thinks it is oil; but neither of these gentlemen exclude other principles.

3. He supposes the vegetable food to consist of exceeding fine particles, which adhere to the sides of the pores or cavities of the soil, and these cavities he calls the *pasture* of plants, because from them the roots collect the vegetable food lodged there. Tillage divides the soil, multiplies its cavities or pores, and opens a communication between them, whereby the roots have a free passage through the soil. The effect, therefore, of tillage is to enlarge the *pasture* of plants, but does not encrease the *food* itself. On the contrary, the more perfectly land is tilled,

tilled, the sooner it will be exhausted of its vegetable food, by the roots extending more freely therein ; unless it is supplied with new vegetable food elsewhere. This fresh supply it receives from the atmosphere, and receives it in proportion to the goodness of the tillage, and frequent repetition of it, at proper times and seasons. “ It has, says Mr. Tull, p. 23, been often observed, that when part of a ground has been better tilled than the rest, and the whole ground constantly managed alike afterwards, for six or seven years successively ; this part that was but once better tilled, always produced a better crop than the rest, and the difference remained very visible every harvest.

“ One part being once made finer, the dews did more enrich it ; for they penetrate within, and beyond, the superficies whereto the roots are able to enter. The fine parts of the earth are impregnate

pregnate throughout their whole substance, with some of the riches carried in by the dews, and there repositied; until, by new tillage, the insides of those fine parts become superficies; and as the corn drains them, they are again supplied as before. But the rough large parts cannot have that benefit; the dews not penetrating to their centers, they remain poorer."

And, p. 63, speaking of successive crops of wheat, obtained by the new husbandry, without manure, he says; "If it should be demanded, from whence the soil can be supplied with vegetable matter, to answer what is carried off, by these constant crops of wheat, that the land be not consumed by them: he answers, the soil in this our case, cannot be supplied in substance, but from the atmosphere." And then he proceeds to shew, how the vegetable food is increased, in well tilled land, by the dews,
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rain, &c. that descend upon it from thence.

The earth, therefore, that he says is the vegetable food, is not the common crude earth, but such as has been prepared in the atmosphere. Nor did he imagine, that the particles of the earth could be so minutely divided by the plough, as to fit them to enter into the roots of plants; but says, p. 15, "As to the fineness of the pabulum of plants, it is not unlikely that roots may insinuate no grosser particles, than those on which the colours of bodies depend; but to discover the greatest of those corpuscles, sir Isaac Newton thinks will require a microscope, that, with sufficient distinctness, can represent objects five or six hundred times bigger than, at a foot distance, they appear to the naked eye." Such a degree of minuteness, as is impossible to be attained by so rough an instrument as a plough.

I shall mention only one more instance of the misapprehension of Mr. Tull's system, by Dr. Home, p. 40, "That the communication of the earth, says he, by the mechanical action of the plough, is not the chief means of increasing the vegetable matter, as Tull asserts, appears plainly from these two facts; that even the lightest soil is the better of fallowing; and that when fallow ground is laid up in ridges, more benefit is received than when it is left quite flat."

The mechanical action of the plough, and good tillage in general, prepares the earth to receive the vegetable matter, and so far is the means of increasing it; but the increase of it is not the immediate effect of ploughing, but of the influences of the atmosphere; and this is what Mr. Tull asserts. The doctor's two facts produced against Mr. Tull's Theory, are the very same he has insisted upon in support of it. He has shewn at large,
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the benefit of frequently ploughing light land, in order to prepare it for receiving the vegetable matter from the atmosphere: and proves from reason and experience, that laying land in ridges makes it more susceptible of that matter, than laying it flat; because when laid in ridges, a larger surface is exposed to the atmosphere. The mistakes made in this matter, seem to have arisen from not distinguishing what Mr. Tull has said of the *food* and *pasture* of plants; or perhaps from perusing some imperfect edition of his husbandry; his original work being very scarce. — But to return from this digression.

As vegetable and animal manures contain the principles of vegetation, salts, oils, &c. and are found to be great fertilizers of land, it is generally thought that they have this effect from their fermenting, putrifying, and dissolving in the soil, and their entering the roots of the growing plants, for their food and

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nourishment; and thus the salts, oils, &c. of the dung and other such manures laid upon land, are supposed to furnish the salts and oils of the crops that grow upon it.

Though this is a plausible way of accounting for the operation of these manures, there are some material objections to it. For land is fertilized by pulverization, and the consequent influences of the atmosphere, without the salts, &c. of manure. This is fully proved by the new husbandry. The plants cultivated in that way without manure, grow as vigorously as if manured with dung; and are found to contain the very same principles, and no other, that plants of the same kind contain, which are dressed with rich manures. This clearly shews that the hoed plants receive their nourishment, their salts and oils, from the atmosphere, and not from any salts and oils originally in the earth. For if any
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Such were in it, before this tillage was begun, a few crops would exhaust them; as we see they do the fertility of new-broke land, or land enriched by fallowing; unless the fertility of such land is recruited by tillage or manures. But in the way of horse-hoeing, no manures are necessary to recruit the land; but its fertility continues, notwithstanding the crops produced, and carried off from it every year, so long as the hoeing culture is continued.

As it is a fact, that horse-hoed plants grow as vigorously without manure, and contain the same principles as manured plants; whether they are manured with any one kind of manure singly, or with a composition of different kinds; also that land dressed with manures that contain no oils or salts, as marle, chalk, and lime, nourish plants as well as if dressed with such manures that contain the largest proportion of both; it seems from hence

very probable, that plants receive their nourishment from the atmosphere, in one case as well as the other; and that the essential parts of plants are not communicated to them from manures.

The effect of vegetable and animal manures, and of the hoeing husbandry, in one respect is the same: they both open and pulverize the soil; whether these manures have any other considerable effect, is not certain.

It is indeed true, that dung enriches land to a greater degree than tillage; but this does not prove this to be the effect of its salts, and oils, in any other respect than pulverizing the land: for tillage without manure enriches land; more tillage enriches it to a greater degree; if this land is then dunged, it will be still more highly fertilized. In the first case, its increased fertility arises plainly from its being more pulverized; why therefore should not this effect of
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the dung be from the same cause, viz. a further pulverization? for putrescent manures do, for a time, divide the soil more than tillage.

In a dunghill, the putrescent ferment makes the salts and oils of it volatile; and being exhaled into the air, an earth only remains, of no great efficacy to enrich land: if the dung is laid on the land, a fermentation also ensues, and the salts and oils being there likewise volatilized, ascend into the air; all of them, as some think—a considerable part of them certainly do; and therefore do not furnish the crop with any vegetable food; what remains seems insufficient for that purpose; so that the principal effect of dung, appears to be the breaking and pulverizing the soil, by which it is prepared to admit the riches of the atmosphere.

But supposing that all the principles of the dung did remain in the soil, it is by no means clear that they furnish the ali-

ment or vegetable food to the crop. To do this, they ought to consist of such kind of matter as is suitable nourishment to the plants they are to feed. But dung of only one sort is supposed to give nourishment to all crops, to many thousand species of plants; and all kinds of dung are supposed to feed all kinds of plants; though it is certain that the principles of all the various kinds of plants are different, as appears from their different virtues and effects. Hence it seems, that dung would be more likely to poison many plants than to nourish them.

To solve this difficulty, it is said, by those who contend that dung and other animal and vegetable manures are the food of plants; that plants have a power of altering their food into their own nature; that they can change alkaline salts into acid, and oils of different natures into those of their own; and it seems by this way of reasoning, that plants could
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change salts into oils, or oils into salts, &c.

This opinion is expressed by Dr. Hunter, in his Essay on Vegetation and Motion of the Sap, as follows: " We reason improperly when we say, that every plant takes from the earth such particles as are natural to it. A lemon engrafted upon an orange-stock, is capable of changing the sap of the orange into its own nature, by a different arrangement of the nutritive juices. A mass of innocent earth can give life and vigour to the bitter aloe, and to the sweet cane; to the cool houseleek, and to the fiery mustard; to the nourishing grains, and to the deadly night-shade.

" The universal juice of a plant, is a limpid subacid liquor, which flows plentifully from a wound made in a tree, when the sap is rising. The birch and the vine yield it in great abundance. This liquor as it moves through the innumerable

able small vessels, becomes more and more concocted, and is the general mass from which all the juices are derived: it may be called **the blood** of a plant. By a certain modification it produces high flavoured oils, gums, honey, wax, turpentine, rosin, and even the constituent parts of the plant itself. How this *transmutation* is performed, remains, and perhaps ever will remain, unknown."

This opinion seems to imply, that there is but one kind of matter in the universe; and the distinctions made of different kinds, as of air, water, earth, salts, oils, &c. are only different arrangements of it, the same matter differently concocted or modified; which is entirely contrary to the received doctrine of original elementary principles, whereof all bodies are compounded: for if there are such principles, essentially distinct, the nature of them cannot be changed by any arrangement, by their passing through
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the vessels of plants, nor can there be a *real transmutation* of elements by any power less than His who formed them with these distinct qualities.

The doctor gives a different account of this process elsewhere; "The air, says he, contains, especially during the summer months, all the principles of vegetation. Oil for the perfect food, water to dilute it, and salts to assimilate it. These are greedily absorbed by the vessels of the leaves and bark, and conveyed to the innermost parts of the plant, for its growth and fructification. When the air happens to be cold and moist, this absorption takes place; when it is hot and dry, the same vessels throw off the superfluous moisture by perspiration.

"At the extremities of the roots of plants, we observe a spongy kind of excrescence, pierced with innumerable small holes; through these the nutritive juices of the earth are absorbed.

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“ The bark and leaves of a plant imbibe at proper seasons the moisture of the atmosphere : at other times they perspire the superfluous nourishment.”

Here we see an ample provision made, of oil, water, and salt, absorbed by the leaves and bark from the atmosphere ; and of the nutritive juices of the earth, absorbed by the roots ; plants being thus provided with such abundance and variety of the nutritious matter, from the earth and atmosphere, why should a *transmutation* be supposed, where it does not at all appear necessary to suppose it ?

Dr. Grew, in his curious Anatomy of Plants, gives a clear account of this process of vegetation, and in treating of their trunks, p. 132, expresses himself as follows ;

“ If it be asked, says he, how a plant comes to have any oil at all in any part : since we see that the sap, by which the root is fed, seemeth to be nothing else
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but water ; and that many plants which yield a great deal of stillatitious oil, as mint, rue, and others, will not grow in water : I say if it be enquired how this water is made wine or oil ? I answer there is no such matter : but that the oil, and all other vegetable principles, are actually existing in, and mixed *per minima*, though in an extraordinary small proportion, with the water. Even as we see the distilled waters of annise-seeds, penny-royal, and the like, to be impregnated with their own oils, which give the taste and smell to such waters.

“ I say therefore, that all kinds of vegetable principles, are either in, or together with, the water, with less difference first received into a plant. But when they are once therein, they are there separated, that is to say filtered, some from others, in very different proportions, and conjunctions, by the several parts ; the watery by one part, the aery
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by another, and so the rest ; and so every part is the receptacle of a liquor, become peculiar, not by any *transformation*, but only the percolation of parts, out of the common mass or stock of sap. And so all these parts of the sap, which are superfluous to any kind of plant, are at the same time discharged back by perspirations into the aer."

Hence it appears that the use of the innumerable fine vessels of plants, is not to change the nature of the matter that enters them by the roots or other parts, but to assort the particles of them for the use of the plant, its growth and nourishment.

Here we might conclude this point, but that doctor Home has referred to an experiment, in support of the opinion of transmutation, which it is proper to take notice of, experiments being the surest means of attaining a real knowledge of the operations of bodies.

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“How strong, says the doctor, p.179, the power inherent in the vessels of plants, to change and alter these substances which are taken in, appears from an experiment of Homberg. He filled two pots of earth mixed with some salt-petre: into one he put cresses, which is an alkaliescent plant, and affords a volatile alkaline salt, but no acid; into the other, fennel, which is an ascescent plant, and affords an acid on distillation, and no alkaline volatile salt. He filled two other pots with earth, which had all its salts washed out, if there were any in it. Into one he planted fennel, and into the other cresses, as in the former. The two plants in the nitred parts grew much better, and weighed much more than in the pots without nitre. The cresses in the nitred pot, when distilled, gave no acid salt, though fed on a salt which contained an acid. The fennel fed in the washed earth, gave an acid, though there was
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none in the earth. This experiment shews, that the vessels of plants have a power of changing the salts taken in from the earth, into their own particular natural one; probably by combining them, with different proportions of water, oil, earth, air, and the particles of light which issue from the sun."

In this experiment, the two plants that grew in the washed earth, produced their natural salts, one acid and the other alkaline; these they received from the atmosphere, for in the earth there were no salts. One of the plants in the nitred earth produced no acid salt; though, says the doctor, it was fed on a salt which contained an acid. But how is the doctor certain that it fed on the salt? Did not the fennel in the washed earth give an acid; though it did not feed on any salt? Whence had it that acid, but from the atmosphere? And might not the plants in the nitred pots have their salts from
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thence also? The plants in the nitred earth growing much better and weighing more than those in the washed earth, is no proof that they fed upon the nitre, and in consequence thereof grew so much the more vigorously: for why should this salt have such an effect, more than the other parts of their food, their oils, or earth? This will rather be an argument that they did not feed upon the nitre, but that the nitre acted as a manure, and by dividing the earth, and multiplying its pores, as other salts and manures do, a larger share of the contents of the atmosphere was then deposited, which made these plants grow more vigorously. And admitting that some of the nitre did enter their roots, and none of it was to be found in the cresses; it is to be observed that plants perspire plentifully, and that they may, as animals, by that means, discharge such particles as are noxious, or unsuitable to them.

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In the researches made to discover the nature of the vegetable food, it is usual to analyse plants, and earth, supposing that this food is to be found in one or both these. But if plants have a power to alter or change the nature of the substances absorbed by them, how is this food to be discovered. The doctor made several experiments upon earth, and says, p. 15, 16, that in some rich mould he found an alkaline salt. If cresses was raised in this earth, it would, upon distillation, produce an alkaline salt; and fennel raised in the same earth, would produce an acid salt. To what purpose then is the examination of the constituent parts of earth? The plants raised in it will contain their own proper salts, however different from those in the earth. The same may be said of chemically examining the plants; in some are found salts of one, and in others of different kinds, but this determines nothing of

the vegetable food, of what kind it was, before it was absorbed by the plants; for the same difficulties occur with regard to their oils and earths, as their salts.

But it is not necessary to prosecute these arguments farther, as we have no certain proofs that plants can change the nature of those substances absorbed by them, at their roots, bark, or leaves; any otherwise than by dividing, assorting, or combining them.

In regard to the operation of manures vegetable and animal, and particularly of dung, though the sort most commonly used of any, few experiments have been made on purpose to discover whether it furnishes the vegetable food, or acts only as a pulverizer of the earth. One has been made, by the author of the Complete English Farmer, to determine this important point, which he relates as follows ;

“Pulverizing the earth, says he, p. 117, is not the only use of dung, though the following experiments, I must own, seem to prove it. I caused a quantity of virgin earth to be rubbed fine enough to pass through a sieve, and then divided it into three equal parcels. I mixed with two of these parcels a quantity of dung, equal in weight to one fifth part of their whole substance; one part with stable dung, from a fresh dunghill, the other taken from the bottom of an hot-bed; the third parcel was left without manure, and the same weight of earth added to it, as of dung to the other two parcels. The weight of the virgin earth in the two pots mixed with dung, was 15lb. in each; and the proportion of dung was 3lb. in each; the weight of the virgin earth in the mixed pot was 18lb. Those three parcels thus composed, were filled into pots of twelve inches diameter, and into each of these pots I planted five grains from the

the middle of the same ear of wheat, in this quincunx manner . . . , each grain being just two inches apart from every other grain, and I planted them with a gage, each one inch and a half below the surface of the earth. I was very exact in the size of my pots, lest an increase of surface, might cause an increase of vegetable food. Having done this, I placed the three pots upon a level spot in my garden, each one foot from the other, on the 7th day of October 1769.

“ I marked their progress through the winter, and found the seeds planted in the virgin earth, more vigorous, and more prolific, than those in either of the other two: the plants in the earth mixed with the rotten dung, were next in vigour and increase: but those planted in the fresh dung, though they appeared the greenest, and rose the highest at first, drooped before the winter was over, sickened in the spring, and before harvest

dwindled to little or nothing. I was prevented from noting the produce of the grain, by the ravage of birds, that almost wholly stripped the ears; but the increase was as follows: from the five seeds in the virgin earth, fifty-six stout stalks arose: from those in the earth mixed with rotten dung, thirty-five, and from those in the fresh stable dung, only twenty, some very puny.

“ I am sensible, however, of the insufficiency of this experiment on two accounts; the first from the want of room in the pots for the roots to spread, and collect food for the nourishment of the plants; and the other, from not attending properly to supply them with water.

“ To obviate these two defects, I have this year varied my experiments, by enclosing the pots in the ground, pressing the earth round them, and then taking them out, leaving their exact impression behind, in which I have filled the same
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quantity of well pulverized earth, mixed exactly in the same manner, as was last year confined in the pots themselves; by which means the tender fibres of the roots, when they have occupied the narrow space contained in the hollow, may now extend themselves on all sides, and collect nourishment. For it may possibly be, that dung by its warmth, and by its fermentative powers, may stimulate the roots, and cause them to extend their fibres to a greater distance than earth, though equally fertile, yet more at rest, may be capable of; and this may be one essential property of dung, and more particularly of fresh dung, without which it may lose part of its effect.

“ A third defect in this experiment, for the purposes intended, might arise from the choice of virgin earth, which has been observed to contain within itself, all the requisites for the production of a single crop. To the increase of this

earth, by substituting an additional quantity of it in the room of dung, the extraordinary increase of stalks, may probably have been owing; but to remove this objection likewise, I have this year filled the pots with earth, from part of a field fallowed for wheat, which has been cropt for two years before, without any dressing: so that the result of this experiment will, to me, be a satisfactory decision of two very interesting questions to husbandry: one, whether dung is of use only as a divider of the soil; the other, whether fresh or rotten dung are the most powerful in promoting vegetation. The public shall in due time be made acquainted with these discoveries, if life be spared to the writer till the proper season."

It is observable in this experiment, that the proportion of dung mixed with the earth in the two dunged pots, was a third part of the weight of the earth, which

appears to be much too large a proportion of dung: for if the staple of a field prepared for wheat, is eight inches deep, every foot square of good land of that depth, will weigh about half a hundred weight, and the staple of an acre of such land will weigh about one thousand eighty-nine tons; now admitting that thirty tons of dung was laid upon this acre, as a common dressing, which is a full allowance; yet this would be but a thirty-sixth part of the weight of the earth dressed with it, whereas in the experiment, the weight of the dung was a third part of the earth. And if the staple was supposed to be of a greater or lesser depth than eight inches, the proportion of dung in this experiment, would still greatly exceed the quantity commonly used for dressing land for wheat.

Such an excessive quantity of dung, must cause an uncommon degree of fermentation in the soil, more likely to be a
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judice than an improvement to it; and to this was probably owing in some measure, the deficiency of the crops in the dunged pots. Hence likewise the crops of the pot mixed with stable dung, was so much inferior to that mixed with rotten dung, because the fresh stable dung made a still more excessive fermentation.

On the other hand it may be observed, that sifting the earth put into the pots, was a disadvantage to all the crops, but most to that in the virgin earth: for it is allowed by the most skilful gardeners, that sifting the earth causes it to lie too close, consolidates it, and obstructs vegetation. It should be well broke, and the larger stones picked out, but not sifted. The plants in the dunged pots had the advantage in this respect, the earth about them was kept open by the fermentation of the dung, and their roots could more freely extend, than those in
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the virgin earth, which had not that assistance.

Though virgin earth contains in it a considerable proportion of the vegetable food; this does not seem a sufficient objection to the use of it in such an experiment. The same earth was used for all the pots, and it ought to be the same for all, and no other difference but the dung. If such poor earth was used as contained very little of that food in it, it might be too poor to support a crop of wheat till harvest.

With regard to the additional quantity of earth put into the pot that had no dung, there will be no necessity of so much, if only the common quantity of dung is put into the other two pots, which need not be more than a thirtieth or fortieth part of the weight of the earth, which will not make any material difference in the crop, whether it be added to the dunged pot only, or if the
same

same quantity of earth is put into each of the three pots.

And in order to obviate every objection, I would propose a variation in the experiment. Let a trench be dug in hard stale ground, four feet wide, and nine feet long, as deep as the staple of the land; break the earth fine, and pick out the larger stones and roots of weeds; dig and turn this earth frequently for a year, and suffer no weeds to grow upon it. When thus prepared, divide it into three equal parts, lay two rows, or partitions, of bricks, laid flat, and across the trench, as high as the top of it, to prevent the roots getting through them; and at the proper season mix the common proportion of fresh dung among the earth in one division, and of rotten dung in another; the third division to have no dung. Plant all the three divisions with wheat as mentioned in the above experiment, and keep them all clean hand-weeded

weeded till harvest. Plant but one row of wheat, the grains six inches asunder, along the middle of the piece, and the same number of grains in each division.

But if the experimenter does not chuse to wait so long as a year, he may take the earth quite out of the trench, and fill it with virgin, or other proper earth, mixed as before mentioned, with due proportions of rotten and fresh dung, in two of the divisions.

In this way of planting, no watering will be necessary, which when it can be done, should be avoided in such experiments. Rye is not so liable to be destroyed by birds as wheat, and is proper for such an experiment; but if wheat is planted, it must be defended from birds by nets; sufficiently fine to keep them out. Otherwise, as appears from the experiment, and I have always found, there is no guarding against the birds without covering the corn with nets, so
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securely that they cannot get through, or under them: and it is material to know, not only the number of stems produced, but also the fullness of the ears and grain.

The experiment thus conducted, will determine which is the most proper to use, fresh or rotten dung; but I doubt will not determine the other point, viz. whether the effect of dung is only to divide or pulverize the soil, or whether it also furnishes the vegetable food to the crop. For suppose in the above, or other such experiment, the dunged earth produced the largest crop; as no doubt it will, if the experiment is in every respect rightly conducted; the cause of this superiority will be justly attributed to the dung, but the manner of its operation will still remain undetermined. This should not, however, deter those who have opportunity, from attempting to discover this by experiments, as the know-

knowledge of it is of real importance and use in husbandry.

Of the various substances made use of by farmers to fertilize their land, there are four that may be reckoned the principal single manures, as they are in more general use than others, laid on in larger quantities, and they have more lasting effects; these are marle, chalk, limestone-gravel, and lime.

Marle is a fossil body found in the earth, a manure of great value, and many estates have been very much improved by it. There are several sorts of it, chiefly the four following, viz.

1. Clay-marle; so called because it resembles clay, though a very different body. It feels soft and oily, and is found sometimes lying near the surface of the ground, and some deeper, especially under beds of strong clay, where it is often found. It is of various colours, red, blue, black, white, and yellow; but the colour

lour is immaterial, being no certain indication of its quality; though many farmers have long thought otherwise, founding their opinion upon the colour of marle that they had experience of its goodness; and for this reason, some have recommended the yellow marle as the best, others the blue, red, &c. But we have now much more certain methods of investigating them, for which the public is obliged to the ingenious Dr. Ainslie, who has lately made very curious experiments upon the several sorts of marle.

2. Stone marle; which approaches to the hardness of stone, and is therefore easily distinguished from the clay-marle, and is of slower operation.

3. Slate-marle; this lies in thin layers resembling slate, and is also harder than the clay-marle.

4. Shell-marle; which is a composition of earth and small shells; it is of a lighter substance than the others, lies
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near the surface of the earth, in low grounds that have formerly been overflowed with water; and sometimes near the sea. This is a very rich manure, and of quicker effect than either of the former.

The marles are all compounded of the same kind of materials, in different proportions, viz. a calcareous earth, clay, and sand; and in some marles are found some shining flakes of foliaceous talc, unsoluble in acids, and very little altered by fire.

There are several kinds of earth that resemble marle, but the following easy experiments will distinguish the true marle from other earths. First put a little fresh dug clay marle into a glass, and pour upon it as much water as will cover it, the marle will soon dissolve in the water into a soft soapy substance; or if exposed some time to the air, it will fall down into a fine powder. Secondly, marle

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effervesces with all acids; a little of it put into a glass with vinegar, a brisk motion will immediately be excited, it will effervesce, rise like wine or cyder, and air bubbles will continue to rise, till the acidity of the vinegar is destroyed. Some other kinds of earth will fall down in water or air; but whatever body has this property, and also effervesces with acids, the farmer may conclude to be marle.

It will be of use to farmers not only to distinguish marle from other bodies, but likewise to discover, before they make use of it, what proportion any marle contains of calcareous earth, clay, and sand. This he may readily do in the following manner.—

Having dried and powdered the marle to be examined, pour upon any weight of it a small quantity of water. To this mixture, well shaken, add a little of the acid of sea-salt, and when the consequent

effervescence is over, add a little more of the acid. Repeat this addition at proper intervals, till no more effervescence ensues. Then throw the whole, with an equal or greater proportion of water, into a filter of brown paper, whereof the weight is known. When all the fluid parts have passed through, fill up the filter, again and again, with warm water. By this means, the dissolved particles of calcarious earth, adhering to the residue, or entangled in the pores of the paper, will be washed away, and nothing but what is really unsoluble, will remain in the filter. This *residuum*, with the filter, is then to be completely dried, and weighed: the difference betwixt its weight, and the original weight of the filter, gives you the weight of the unsoluble parts (the clay and sand) contained in the marle under examination. This being known, the proportion of calcarious earth therein, is evident.

Here it is to be noted, that a vegetable acid, as vinegar, is not proper for this experiment, because all the calcareous earth in marle cannot usually be extracted by it: for after the usual filtration, the residuum effervesces with acids. Neither is the vitriolic acid proper for this use: for though it effervesces with all marles, it does not dissolve their calcareous earths, but only forms with them a whitish coagulum, which will not pass through the filter. But all the other mineral acids, may be employed to equal advantage; as the acid of sea-salt, nitre, &c.

The proportions of clay and sand, contained in the *residuum* or unsoluble parts of this process, are discovered by *elutriation*, which is thus performed. Having weighed the dry residuum, mix and shake it well, with a sufficient quantity of water: and after allowing a little time, for the grosser parts to subside;

let the water, with the finest part of the clay suspended in it, be gently poured off, then add more water to the remainder, and after sufficient mixture and subsidence, pour off that likewise. In the same manner repeat this operation, again and again, till the water comes off perfectly pure; the substance that then remains is sand, mixed, perhaps, with some flakes of talc; and whatever this substance wants of the weight of the residuum employed, is the weight of pure clay, carried away by the water in this process of elutriation.

This experiment, for discovering in marle what proportion it contains of calcarious earth, clay, and sand, is not proposed as a matter of mere curiosity; but the farmer who will take the small trouble of examining marle in this manner, may thereby know for which of his lands the different sorts of marle is most proper: for though marles will fer-

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tilize all sorts of land, yet not equally. Those marles wherein he finds the largest proportion of clay, are most proper to lay upon his sandy light land, and those that contain the most sand, for his strong land; the calcarious earth fertilizes both sorts of land, the light and strong.

It is not only useful to examine marles, but likewise other sorts of earth, that have a promising appearance of being good manures, some of which are highly pernicious to land. Among these there is one sort, often found in the same bed with the best marle, of a darkish lead colour. Instead of fertilizing ground, it renders the best soil incapable of bearing any kind of vegetables for many years; Dr. Home, says he has seen the spots on which it was laid entirely barren three years afterwards, and had heard of its effect continuing, in other places, for a much longer time.

If a piece of it is examined that has not been much exposed to the air, it differs

fers very much in taste from marle. Instead of the smooth unctuous taste of marle, this body tastes acid, and remarkably astringent. It falls down to a powder in water, like marle; but raises no effervescence with acids, nor in the least destroys their acidity, which plainly distinguishes it from marle. It turns syrup of violets red, which shews it contains an acid; whereas marle, like all absorbent earths, gives it a green colour.

The Dr. found by several experiments, that this body consisted of an earthy body like clay, a small proportion of a volatile vitriolic acid, and about an eightieth part of salt of steel. To this salt he attributes the poisonous quality of this body. If any of it should by mistake be used as manure, he thinks it may be corrected with marle; but this is uncertain; and the best way is for the farmer to examine such earths as he supposes to be marle, and intends to make use of for

manure, before he lays them on the land. If they do not fall down in water, and effervesce with acids, he should reject them.

It may however be of use, to try to correct the pernicious effects of such earths with marles, as the doctor proposes; or with chalk: for it is not uncommon to find land tinged with steel, iron, or other metallic mixtures; and if the ill effects of these could be cured or mitigated by marle, it would be a valuable discovery. Perhaps, as he supposes, a considerable share of the good effects of marle in all grounds, may be owing to this special effect, viz. the destruction of bodies, which, in proportion to their quantity, destroy all vegetation.

We have a striking instance of the poisonous quality of this lead-coloured earth, that so much resembles marle, in the Complete English Farmer, who says he was once ensnared by it.

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“ In digging a well, says he, on the side of a clay hill, the workmen met with a stratum of this lead-coloured earth, ten feet deep, and threw up a great quantity of it. As it was near a public road, many farmers cast a longing eye towards it: they felt it, and as it was unctuous and slippery, they concluded it was marle, and I was offered a crown a load for it. I did not then know the distinguishing characteristics, and I concluded, that if it was worth a crown a load to them, to carry away, it must certainly be worth more to me, to use upon the spot. Accordingly I caused it to be spread plentifully upon an upland meadow, which had received no amendment for many years. It was about Michaelmas when it was laid on, and it had all the advantages of air, rains, and frost, to mellow it; and indeed it was so mellowed, that instead of falling into a powder, it ran into a soft, oily consistence

ance, not unlike new churned butter. In the spring, when I expected the good effects of it, to my great surprize, the grass wore a dead appearance; here and there a green blade among the faded sward; but this like the rest soon drooped, and in short the most amazing sterility ensued. None but my own servants were made privy to the disappointment: for I did not chuse to be laughed at by my neighbours. I was not without hopes, however, of its recovery, but though it is now more than ten years since this accident happened, the land on which this poisonous substance was laid, has not yet recovered its wonted fertility.

“ Doctor Home, attributes its poisonous effects to the mixture of salt of steel in its composition, and I believe very justly: for above this stratum of lead-coloured earth, large quantities of iron ore were discovered, which, on digging clay in other parts of the hill, were found
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here and there dispersed in round lumps, about two or three cart loads in a lump, as if a round hole had been dug, and the iron stone shot into it. Other metallic and fossil substances, were found also in digging this well; and indeed, when at the depth of seventy feet, the water was reached, it was so strongly impregnated with sulphur, that it could not be commonly used. I was not, however, aware of the pernicious effects of the blue clay, till I had read Dr. Home's book, where the description of it so exactly corresponds, in colour and effects, that I think the doctor's accuracy in describing it, and his candour in cautioning the husbandman against its poison, cannot be too much applauded."

From this example may be seen the necessity of examining untried earths, before they are used as manure; and the advantage of having easy methods of determining the genuineness of marle; one
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of the most capital single manures the farmer has to depend upon.

It seems to have formerly been a common opinion, that all rich manurés were so, because they contained much vegetable food. Hence marle was thought to contain a large proportion of salts, &c. but when it was found that it contained no salts, it was then supposed that it attracted them from the air. This likewise is now found to be an error; for, from many accurate experiments, particularly those made by Dr. Ainslie, upon all the marles, that had been long exposed to the air, he found they contained no salts in them of any kind, nor attracted any, except in one instance: this he relates as follows—

“Upon the surface of some marly rocks, which looked towards the north, and had been exposed time immemorial to the open air, I found a thin white efflorescence. In many places where water
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trickled down from the rocks above, moss, to the thickness of some inches, had been in time accumulated, and was now crufted over with a hard white substance. Below this cruft the different plants of moss were found, disposed in a very regular manner, and soldered together by a substance similar to the cruft. Here I expected to have found the salt of marle, but could not by any treatment discover the smallest indication of it. The mineral acids, after a very brisk effervescence, dissolved entirely both the efflorescence from the surface of the rock, and the matter which adhered to the rock. From this circumstance it appears, that those substances consisted solely of the calcarious earth of the marle, freed from the other earths by the moisture, &c. whose action it had for many years undergone.

“ Upon a stratum of marle, which, with others, had been exposed for ages
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to the open air, I found a whitish saline efflorescence, in considerable quantity. This efflorescence was moist, and dissolved readily in water; and alkaline salts added to a solution of it, immediately precipitated a calcarious earth; after separating the earth by filtration, the remaining liquor afforded, by a proper evaporation, many distinct crystals, of a cubical figure; they tasted like sea-salt, crackled in the fire, and by the addition of the vitriolic acid, emitted copious suffocating fumes. Hence it appears that the salt found upon this marle, consisted of the muriatic acid, united to a calcarious earth.

“ It is singular that no vestiges of this salt appeared upon any of the beds of marle but one, and this one had nothing peculiar, either in its composition or situation. It differed from the rest in this only, it was possessed of a greater degree of moisture.

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“ Those marles were exposed alone to the air; whether when incorporated with the soil, such substances may be more readily converted, in their calcarious part, into salt proper for the nutrition of vegetables, experiment alone can determine. Some circumstances in the manufacture of nitre, seem to persuade us that they may. On the contrary, observations are not wanting, which appear to take greatly from the probability of such an opinion: for marles are found to produce the most remarkable effects on light exhausted soils, where they can find little or nothing proper for furthering the nitrous process, or the production of any salt we are yet acquainted with. However that may be, I think we are authorised by the foregoing experiments (made upon these and other parcels of marle) that marle acquires nothing of a saline nature, by being exposed alone to the open air.

“ If no salt is formed upon marle, from its exposition to the air, how does
marle

marle operate? An answer to this question, would necessarily lead us to consider the operation of manures in general; a subject too extensive and intricate to be discussed within the narrow limits of this essay."

That in one only bed of marle salt should be found, though all had the same situation and exposure, seems to have been from some unobserved circumstance in that bed; and the obvious conclusion from the whole is, that marle in general does not attract salts from the air. The question then, how does marle operate, is, as this gentleman observes, difficult to be resolved. There is however one circumstance that may in some measure lead to a solution.

It has been observed that the particles of marle lose their tenacity, and fall into powder, in water, and it does not appear that they can be again united, but rather that they have then a repulsive property. This property in marle is very different
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from clay ; which though it will also dissolve in water, recovers its adhesive quality when dried ; becomes then as hard as before ; and will burn into brick, which marle will not ; and as marle consists of very fine parts, and these are so readily separated, they will ferment and incorporate with the soil, will open, and very minutely divide it, and by that means enrich it, as was before explained of other fermenting substances.

Some farmers were formerly of opinion, that strong land was not much improved by marling ; probably because they did not bestow upon it the due quantity of marle ; and likewise because, as we have shewn, that some marles having in them a large proportion of clay, are not so beneficial to strong clayey lands, as those that abound more with sand in their composition. This is not discoverable by the colour and appearance of marle ; and farmers did not otherwise know how to distinguish them.

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Strong lands, and even clays, are so much opened by marle, that they are made much mellowed by it, and drier. And as it opens the soil, the superfluous water, which before kept the land cold, finds an easier passage through it, and then it becomes warmer, and produces the crops earlier than before. Such are the effects of other manures that open and divide the soil, and plainly indicates that this is a principal effect of marle.

In confirmation of this, it is found by experience, that cold, sour, grass-grounds, which produce rank weeds, when plentifully marled, the rank weeds are killed, and in their room the white clover springs up in such abundance, as if the land had been sown with the clover seed. Some others that are called warm manures, as soap-ashes, &c. have a similar effect. These warm the land by their salts, and marle by drying it, which also makes it warmer; the effect
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of both is to destroy the weeds that thrive best in moist cold soils; and encourage the growth of clover, that delights in drier land.

In light land the effect of marle appears to be different. The fault of such land being a deficiency of moisture, letting the rain pass too quickly through it, because it consists of too gross parts, and the cavities of it are therefore too large. The great benefit of marle to such land, seems to consist in its fineness and very minute parts, which partly fill the cavities of the light land, makes it retain more moisture, and therefore cools it. What confirms this operation of marle is, that, in general, clays, and all strong earths, have in them the largest proportion of fine particles; and all such earths are allowed to be great improvers of too light, dry, warm lands. I might add as a further confirmation of this effect of marle, that these light lands are much

improved by frequent and thorough tillage, which breaks them into smaller parts, and makes them lie closer; by which means their cavities are made smaller, they better retain the dews and rain, and are evidently rendered thereby cooler, and more fertile: and as marling these lands has the same effects, the cause is most probably the same.

Stone and slate-marles being harder than clay-marle, are longer in dissolving, and their effect slower than clay-marle, for which reason a larger quantity of them should be laid on the land, about thirty-five cart-loads, or more, to the acre, and of clay-marle, about twenty-five or thirty loads. Shell-marle being a strong manure, but of an open, loose contexture, and of quick operation, ten or twelve loads may be sufficient. If too much of it is laid on at once, it will raise a strong fermentation in the land, and cause it to swell so much, that the plants will

will be in danger of being turned out of the ground, or lodged; and as the nature of the land and other circumstances are various, it is safest to lay on this, and all the marles, moderately at first: and afterwards, if found necessary, the quantity may be encreased.

Marle is apt to subside or sink down in the land, below the operation of the plough; and for this reason some have advised to lay it on the surface, or plough it in very shallow. But it is better to plough it in to a moderate depth, well mix and incorporate it with the land; and in a few years it may be brought up again near the surface, by ploughing the land a little deeper than ordinary. The best time to lay it on is between Michaelmas and Christmas, that it may be mellowed by the rains and frost, and when thoroughly broken, spread it very even upon the land before it is ploughed in. A good dressing with marle, will very

much improve the land for fourteen or fifteen years.

Sometimes marle lies so near the surface of the land, that the farmer may find it in the sides of his ponds and ditches, but more frequently by boring the land with a common two or three inch auger, that has a jointed stem, eight or ten feet long. Such an instrument is very proper to discover marle, clay, peat, or other soft earths, that do not lie at a great depth. It should be drawn up often, and the earth it brings up examined, and cleared out. But when the harder deep fossil earths are to be searched for, another instrument is to be used, such as is recommended by the marquis de Turbilly, from long experience of its use. It is a round iron rod, about an inch in diameter, made in joints each about three or four feet long, and to screw one into another. At the bottom of the lower joint is screwed in a strong blunt steel point,

point, and a little above that, there is a groove made in the rod, near half an inch wide, and deep, and four or five inches long. There is likewise an iron handle to go across the rod, and fasten to it, but so that the handle may slide up and down upon it; several small holes are made through the rod, and one through the handle, and by putting an iron pin through both, the handle may be confined to the rod, higher or lower as shall be found necessary. The handle is to draw up the rod by, and being thus fastened, prevents its slipping down out of the hand, and being lost.

When this borer is to be used, begin with one or two joints only; it is to be lifted up, and let fall perpendicularly upon the place where it is to enter the ground, which it will do by its own weight, a little way at first, and still deeper every time it is lifted and let fall down in the same hole. When it has

penetrated to the top of the joint, screw another on, till it has gone as deep as required. As it will penetrate some inches deeper at every stroke, the groove at the bottom should be often searched, and the earth taken out of it, put into papers, and numbered; by which will be seen, as the rod descends, what kinds of earth lie, at different depths, below the surface; and is of excellent use for discovering marle, chalk, lime-stone, coal, fuller's-earth, tobacco-pipe-clay, and other valuable earths and fossils fit for manure and other purposes, where it was not suspected that there were any such: for, as that excellent husbandman, sir Digby Legard, has observed; "I cannot, says he, help thinking, that every soil either contains within itself a remedy for its original barrenness, or, at least that no large tract of country is destitute of some peculiar productions adapted to its fertilization, so as to render it fit for the
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production of vegetables, and the support of animals—But the treasures of nature are not always obvious, nor her productions spontaneous.” This kind of borer, has, by still adding more joints, gone to the depth of an hundred feet, and will penetrate into beds of slate and stone marle, and even into lime-stone, and stone of other kinds. The expence of boring is not much, as one man can bore with such a rod forty or fifty feet deep, which if done every four square perches, may be sufficient, or if thought proper to go deeper, and the borer is, for strength, made thicker, it may be worked by two men.

If it is desired to know whether there are any springs in the ground, a little dry sponge put into the groove, will discover them, and at what depth they lie; for the sponge will be made wet in passing through them. This is of use to be known, when wells are intended to be dug,

dug, or lucern and other deep rooting plants are proposed to be planted, that will not live where their roots reach water.

Chalk is another valuable manure, found in several counties of England in great plenty, but little or none of it in Scotland, nor in Ireland. It is a fossil body, consisting chiefly of a calcarious earth, and readily burns into lime: some of it is of a soft, soapy quality, which is reckoned the best for manure: it is somewhat of the nature of marle, and is called so in the Isle of Wight. It is often found near the surface of the ground, lies in beds as free-stone, and frequently to a great depth.

Chalk is in general of a dry quality, and consists of very minute parts, and hence it seems to be so great an improver of clayey and other lands. When dried by the sun and air, it will not fall down into powder among water, as marle does,

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but becomes almost as hard as some kinds of stone: for this reason it should not be dug and exposed to the air in summer. The best time to dig it up is in the beginning of winter, from Michaelmas to Christmas, and to carry it upon the land as soon as dug; for then it is moist, and will dissolve by the rain and frost; but will not dissolve in a long time, if suffered first to become dry and hard. When laid on the land, the large pieces should be immediately broke small, and still as it dissolves should be evenly spread upon the land, and ploughed in. If this is done carefully, the whole will be fit to plough in by Candlemas; but none of it should be ploughed in till thoroughly broke: and the whole should be well mixed with the land by ploughing and harrowing.

About thirty cart-loads of chalk, thus managed, will be a moderate dressing for an acre of strong land, which it will en-

rich for fourteen or fifteen years. But, like marle and some other manures, chalk subsides through the soil, till it gets below the tillage, and may be found lying there in a thin cake. By ploughing the land a little deeper, the chalk is again brought up, and will have the same good effect as before.

It is customary with some farmers to mix dung with chalk, when first laid on; and others give a dressing with dung, every fourth or fifth year after chalking; which without doubt adds to the fertility of the land. But if the chalk is prepared as above mentioned, and a sufficient quantity laid on, suitable to the quality and condition of the land, no dung will be necessary at first, nor till the land begins to abate of its fertility, which after some years it will do, by part of the chalk sinking down below the action of the plough, and the effect of so much of it being thereby lost, till the whole

whole is brought up again. For this reason it is necessary to add more chalk, to supply the room of what sinks down, or to supply that deficiency with dung, till the chalk is all to be ploughed up again.

Chalk has been long used as a great improver of clays and strong loams, and thought to be improper for light land; but it is now found by experience to enrich all sorts of land, the light as well as the strong. To understand the reason of this double effect, I shall refer the reader to what is said of marle. Chalk, like marle, opens and mellows clays, and consolidates light soils. Not because it contains any of the vegetable principles, as salts, &c. or that it attracts them from the air. For pure chalk is naturally barren, and no salts are found in it. The author of the Complete English Farmer, indeed supposes, that chalk contains in it the principles of fire, because it warms cold

cold clay soils : but it gives no indication of its containing fire more than other calcarious earths ; its warming cold wet land, being in consequence of its opening such land, by which the water escapes which stagnates in such land, and is the cause of its coldness. And besides, if chalk, had this effect upon cold land, by reason of its heat, it would be pernicious to light hot land, contrary to experience.

That the improvement of strong clayey land by marle and chalk, is from their drying and warming such land, appears from hence, that all sorts of land, strong and light, are made cold and impoverished by wet or too much moisture ; and that they are constantly improved and made warmer by draining, or opening manures. Rushes, flags, sedge, horsetail, and other such plants, thrive in strong and light lands, if water stagnates in them ; because that keeps them moist
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and cold; but let the superfluous water be, by any means, carried off, they will die away.

Lime is another manure of general use, and is made from chalk, and from lime-stone, whereof there are different sorts: the hardest makes the strongest lime. Lime-stone contains a large proportion of calcarious earth, which is of a fertilizing quality: for unburnt lime-stone reduced to powder, is a good manure. But many kinds of stone have little calcarious earth in them, and these will not burn to lime. The way to discover lime-stone, is to pour a little of a mineral acid upon the stone to be examined, as oil of vitriol or aquafortis, and if a brisk ebullition ensues, it may be concluded to be lime-stone: for these acids have no such effect upon any stone that will not burn into lime.

There are different opinions concerning lime, some highly commending it as an excellent manure; others condemning it

it as a great impoverisher of land. The last quoted author says, "That lime laid on, at whatever time, or managed in whatever manner, will, after the first or second year, impoverish every soil it mixes with. Four years ago, says he, upon a hilly field of clay, I limed for wheat, at the rate of sixty bushels upon an acre; and by the persuasion of my seedsman, I sowed near three bushels of wheat, and reaped after the rate of sixteen. The year following oats were sown upon the same field, not through choice, but from necessity, and produced about four quarters upon an acre. The third year, barley and clover, after being winter fallowed and ploughed thrice; the barley did not amount to five bushels, and hardly a blade of clover was to be seen when the barley was mowed, though sowed at two different periods, both favourable enough, as being sown when the ground was moist, and rain succeeded in
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a few days after sowing. The absolute sterility of this field, I wholly impute to the effects of the lime; which though as a manure I decry, yet as a preservative against the ravages of grubs and insects, I most zealously commend. Neither is there any bad effects to be apprehended from the moderate use of it. Ten or fifteen bushels sown upon an acre by hand, in such a manner as to be all equally diffused, will warm and cherish land, when sixty spread with a shovel, will hurt and impoverish it. This caution I thought proper to repeat, because of the indiscriminate use, which the best farmers are too apt to make of this manure."

The ill success of this experiment, seems to have been the principal reason of the auther's decrying the use of lime, for in the preceding paragraph he says, "In Sussex, which runs much upon stiff clay, and all through the North, they always prepare their lands for wheat, by manur-

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ing with lime; and though I do not approve of the practice, from the ill success that has attended my own experiments, yet I cannot believe that it would be universally followed in those countries, if it were discovered to be universally hurtful. Indeed they fallow and lime for wheat; and as no one ventures a crop upon fallow alone, all the merit of the increase, is placed to the account of the lime."

This gentleman's clay-field seems to have been a poor soil, or not in good heart; and the succession of his crops was unfavourable to his experiment; three robbing crops in immediate succession, without any other help than sixty bushels of lime per acre, must impoverish the land; and sixty bushels was too small a quantity to lay upon clay, especially if it was chalk lime, which is the weakest sort.

As to their practice in Yorkshire, where they use much lime, Mr. Young, says,

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“ Is to lay a chaldron and half per acre, thirty-two bushels per chaldron, on summer fallows, either for turneps or wheat. But Mr. Crowe, instead of this practice, has substituted another, which he finds greatly advantageous, and in which thought I believe he is original. It is to throw a chaldron per acre every year, over all the land of his farm, before winter, and plough it in, whether for a crop or a fallow. This he finds to be of excellent service, in mellowing the land with the spring frosts, and dries it in such a manner, that all his lands are, by this means, ready much sooner in the spring for ploughing: an effect which is undoubtedly of great consequence, as it accelerates an early sowing, so important in all crops. The farmers in this neighbourhood, lay from one, to two chaldrons and a half per acre, and find it very beneficial to all sorts of land—The soil here is of two sorts, a loamy gravel,

and a cold wet red clay. Mr. Crow's soil is gravel and clay, but his arable fields all clay."

In other parts of this country, they lay from one to two, three, four, and sometimes five chaldrons of lime upon an acre. I have known three hundred strike, Winchester bushels, of strong stone-lime laid upon the acre of clay ground, and once above that quantity upon a poor lay; which being ploughed in, and the land sown with wheat, the consequence was, a luxuriant, lodged crop. Where lime is cheap, it is common to lay a bushel upon every square perch of land, or an hundred and sixty bushels per acre. But when such large quantities were laid on at once, it is for several years, and the land to have no other dressing: but Mr. Crow's method of liming every year in smaller quantities, is to be preferred. And though in a course of years, the annual repetition amounts, upon the whole,

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to a large quantity, it is plain from his success, that lime is very beneficial, even to very strong land.

“ It is, says Dr. Hunter, generally said, that lime answers better upon sand than clay. This observation will undoubtedly hold good, as long as the farmer continues to lime his clay lands in a scanty manner. Let him treble the quantity, and he will then be convinced, that lime is better for clay than sand. It may be justly answered, that the profits will not admit of the expence—I agree. —But then it must be understood, that it is the application, and not the nature of the lime, that should be called in question. Clay well limed will fall in water, and ferment with acids: its very nature is changed.

“ Lime mixed with clay comes nearest to the nature of marle, of any factitious body we know of, and may be used as such, where it can be had without

much expence. By increasing the quantity of clay, it will make an excellent compost for a light sandy soil: but to make the ground fertile, woollen rags, rotten dung, or any oily manure should be incorporated with it, some time before it is laid on."

"Lime, says another practical husbandman, is one of my favourite manures; as I have seen it work miracles, and, if properly managed by proportion, never fails its proprietor." The proportion or quantity used, is undoubtedly a material circumstance, and so is likewise the quality of it; the lime made from marble, or very hard stone, being abundantly stronger than chalk lime.

Strong clayey lands are very improvable by liming, but the most general practice is to lime light, sandy soils, the effect of which is remarkable, especially at first: for it is by many thought to impoverish them greatly afterwards. Liming them

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a second time has but little effect, the fertility of the land is exhausted, and it is at last in a much poorer state than before any lime was laid upon it. This effect of lime is differently accounted for. Those who think oils and salts mixed with the soil, necessary to vegetation, acknowledge that lime affords neither of these; but they say, that there is a great attraction betwixt quick lime and all oily bodies, and therefore lime must attract oils powerfully from the air and earth, dissolve them, and render them miscible with water. Also that lime seems to have the property of collecting the acid of the air, which it readily forms into a neutral salt, of great use in vegetation; hence, they say, it is probable that lime tends to rob the soil of its oily particles, and in time will render it barren, unless the farmer takes care to support it with rotten dung, or other manures of an oily nature. Also that the excellency of lime upon a

sandy soil, is by mechanically binding the loose particles, and thereby preventing the liquid parts of the manure from escaping out of the reach of the radical fibres of the plants. This is an ingenious theory, but loaded with too many suppositions. For notwithstanding the supposed uses of oils in the earth, it is upon good grounds questioned, whether earth contains in it either oils or salts, as appears from many experiments made by the curious in different parts of Europe, Britain, France, Holland, Switzerland, and Sweden, to discover from whence vegetables are supplied with their food, from water, air, or from earth. These experiments were variously conducted, but similar in the event.

Van Helmont planted the cutting of a willow, - weighing five pounds, in an earthen vessel, having a tin cover, perforated with a number of small holes, wherein he put two hundred pound of dried

dried earth, which he watered as often as necessary. At the end of five years, he took out and dried the earth, and found it had only lost two ounces of its original weight; but the willow had gained an hundred and sixty-nine pounds and three ounces, from the water, or its contents.

Gleditch, Bonnet, and Du Hamel, found, that plants set in moss or sponge, kept in glasses, moistened with water, grew well and flourished, without earth, and that these plants contained the same principles, as other plants of the same sort, which grew in earth. And that mixing the water with nitre, common salt, and even with a solution of rich earth or dung, contributed little to the growth of plants, and that that they throve better in pure water.

G. W. Kraft, sowed oats and hemp-seed in different substances, viz. in rich earth, dried sand, in pieces of woollen cloth,

cloth, and chopped hay: he moistened these seeds with water, and found they grew nearly as well in one of these substances as in the other. But in filings of iron, in ashes of plants not washed, in sand mixed with nitre, in pot-ashes, and in flour, though sown and treated in the same manner, they did not vegetate at all. Dr. Alfson, made nearly the same experiments, with the same success. Salts of several kinds mixed with earth, not only retarded the growth of plants, but put a total stop to it. He found that the most hungry earth, exhausted by vegetation, and sifted, nourished plants full as well as the richest earths. He also remarked, that the hungry earth became much more barren, by being mixed with lime, and that lime water did not promote the growth of herbs or shrubs.

“ From these experiments, says Wallerius, made with the greatest care, repeated with the utmost circumspection, and

and always attended with the same success, we are authorised to conclude, that the earth yields no real nourishing matter to plants, but that their nutritive juices, are derived from water and the atmosphere.

“Trieiwald, in Sweden, and since him Eller, have also lately confirmed these experiments. The latter observed, that the roots of hyacinths, put in distilled water, not only produced perfect plants, but, after being burnt, yielded true earth.

“These experiments prove evidently, that vegetables derive all their constituent parts from water, and air, and even their oils and salts, as well as their earthy particles; as will appear still more plainly from what follows.

“Four thousand different plants can grow in twenty pound weight of earth; and in each of them shall be found a different oil, and a different salt. Let us suppose

pose these plants to be chemically analysed; near an ounce of oil and salt will be found in each. If this oil and this salt, had proceeded from the earth, there must have been in that earth four thousand ounces, or two hundred and fifty pounds, of oil and salt; whereas, in fact, there was not a grain of either of them in it."

Upon the whole, the following conclusions appear to result from these experiments, viz.

1. That the great source of vegetable nourishment is from the atmosphere: from thence the earth is supplied with it, and likewise the air and water; for these, when divested of it, are again recruited, and receive a new encrease of it from the atmosphere.

2. As all sorts of earth are liable to be exhausted of the vegetable nourishment, by the plants that grow upon them, and are again replenished with it from the atmosphere;

mosphere; the difference between rich and poor soils appears to consist in their aptness to receive more or less of that nourishment.

3. This aptness or disposition in different soils, to receive from the atmosphere different degrees of fertility, arises from the number, size, and qualities of the particles whereof these soils are compounded.

4. Rich earths are found to consist of innumerable fine particles, which, when opened and divided, by tillage, manure, or the fermentation excited in them, by the vicissitudes of heat and cold, drought and moisture, are thereby prepared to receive large proportions of the vegetable food from the atmosphere: whereas poor earths, containing a great deal of gross parts, stones, gravels, and large sands, not fit to receive the nutritious matter; and of fine particles, a very small proportion, are not adapted to receive or retain

tain the vegetable food in any considerable quantity, and are much sooner exhausted of it than rich earths.

Hence appears the real source of the vegetable food; and points out the manner in which manures do probably operate upon different soils to enrich them.

There is no sort of manure, concerning which opinions have been more different, than of lime; and as it is to be had in many places, it is a matter deserving particular enquiry, whether lime is of that pernicious quality to land, as by some has been represented; and the grounds of this opinion.

Lime is reckoned a great forcer of land; the meaning of which is, that lime disposes land to exert a much greater degree of fertility at first, than it was before capable of. This is no disadvantage to the farmer; a few large crops of corn being more profitable, than many very poor ones. But then, it is said, that
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after producing these few large crops, the land is so much exhausted, that it ever after remains incapable of being restored, by lime or other manures.

To set this matter in a just light, it is to be observed, that lime has most commonly been used as a dressing, to light, thin, poor soils. That these poor lands being frequently so remote from the homesteads that the farmers could not spare their dung to dress them; or thought the expence too great, of carrying their dung to such a distance; and therefore chose to lime such lands; the effect of lime continuing longer, and the carriage much less expensive than dung; as one load of lime will manure as much land, as four or five loads of dung.

In consequence of a good liming, the farmer expects his poor land will produce him several good crops of corn, and he proceeds accordingly to crop it every year without intermission, allowing it no
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proper change of crops, no fallowing, nor rest; nor any other manure than the first liming; neither does he discontinue his crops, when he perceives the land abating of his fertility. On the contrary, too many farmers are apt to run their land out of heart, not only after liming, but in common practice. Nor is the complaint of impoverishing land, restricted to lime only; the same thing has been said of marling, chalking, and more especially of burn-beating, which enriches land greatly at first, but by a repetition of exhausting crops, is often impoverished to as great a degree as land after liming.

The injury to the land therefore, ought not to be charged to liming, but to over-cropping, and running the land out of heart. Many instances might be given of this; and I have seen some poor fields, that after liming, had been every year cropped with corn, for a long course of years, till they were at last incapable
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of yielding a crop of corn, or even weeds.

Similar to this, Sir Digby Legard describes the bad husbandry practised upon the Yorkshire high wolds. "All the manure, says he, this land gets, is from the sheep-fold, and were he, (the farmer) content to plough no more than he can thus well improve by twice folding, it would be well; but the rage of ploughing is so great, that he every year has been accustomed to plough up a fresh part of his sheep-walk, to take a crop or two, and then let it lie fifteen or twenty years, till the natural grass has again formed a kind of turf: but it will sometimes be forty years before the land is completely sodded over. This ruinous practice is but too common; and where it has long prevailed, the farmer seldom has a threefold increase. He sows four bushels of oats, and three of barley, and is happy if he reaps twelve bushels of the

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former, and nine of the latter. He may plough half an acre in a day with two horses; therefore his crop being worth eighteen shillings, if we deduct twelve shillings for seed, tillage, and rent, his profit is six shillings, but the value of the straw is not equivalent to the expence of mowing, binding, and leading home; two shillings ought to be charged for those articles; and thus is his profit reduced to four shillings *per* acre."

The rent of the wolds is only one shilling *per* acre, and it might be thought that such poor crops were owing to the native poverty of the soil; but this is not the case: for though it is not indeed rich, yet we find, these bad unprofitable crops, are not in consequence of the poor soil, but it is principally owing to the bad husbandry; as appears by the crops received from some of the very same land by Sir Digby himself.

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“ I have, says he, inclosed three hundred acres on the top of the wolds, and have laid down the greatest part with various kinds of grasses. Sainfoin, white-clover, rye-grass, rib-grass, and burnet, which succeed pretty well with me. These grasses taken at an average, a good year with a bad one, and thirty or forty acres together; yield near a ton of hay per acre, on land which never bore any hay before it was inclosed. I esteem this land to be now well worth ten shillings an acre. These three hundred acres were as bad as any in the lordship. I find by experience, that the same land in corn yields, after being well manured, three quarters of barley, and two quarters of wheat per acre. My turnips are worth at a medium thirty shillings per acre, and the clover twenty shillings.”

Here we have a striking example of the effects of different management of the same land. In one case this land

produces on an average but nine bushels of barley per acre per annum. In the other, the same land produces twenty-four bushels of barley, or almost three times the quantity it yielded, under the bad management of the tenants of the wolds.

Lime has been most commonly used upon light, poor land, which it has been supposed to impoverish. No such bad effect is usually observed from liming strong good land: for though good land is also subject to be impoverished by bad management; yet, as it contains a large fund of rich materials, it recovers again in a short time; whereas poor land containing a much smaller proportion of such materials, is sooner exhausted, and long in recovering. Lime is undoubtedly a valuable manure for all sorts of land, but the good effects of that and other dressings, depend much upon the conduct of the farmer. He may by bad management run
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any land out of heart, especially poor land; but this ought not to be imputed to liming. The tenants of the wolds impoverished their lands to such a degree, that they did not when rested, form a new turf in fifteen, twenty, and sometimes in less than forty years; what greater injury than this could liming have done? And yet this same land judiciously cultivated, was worth ten shillings per acre rent.

Where a person has occasion to use much lime, he may burn it himself at a much cheaper rate than he can buy it: and his lime may be burnt more perfectly, and will go farther in manuring: for in lime burnt for sale, there is generally a considerable proportion of raw, or half burnt stones, that are of little or no service to the land at first, or are long in dissolving. Lime when thoroughly burnt, falls presently into a very fine powder, which mixes perfectly with the soil, and acts upon it fully from the beginning; but when not well burnt, a greater quantity

must be laid on the land, and the operation of it is slower and more uncertain. For these reasons, lime perfectly burnt, is most to be depended upon by the farmer, and is the cheapest manuring.

To burn a large quantity of lime at once, mark out a piece of ground with a boundary line in form of a long square. Cut several narrow parallel trenches lengthways of the ground, and others across the former. The ends of these trenches should extend beyond the boundary line. Fill the trenches with brushwood or furze, and lay some larger wood across all the trenches. Then lay a layer of coals all over the foundation, and upon that, a layer of lime-stone broke small. Upon this lay wood or furze, next coals, and then lime-stone. Continue to make layers of these to the top of the clamp. In the mean time walls of turf are to be raised, all round upon the boundary line; and these are to be tied with cross walls of turf, to support the whole while burning.

ing. Some vent-holes are also to be left open near the top of the wall to draw air. And when the wall, and layers within, are raised about nine or ten feet high, the top is to be finished in form of the roof of a house, and covered with turf. Then setting fire to the furze at the ends of the trenches, keep the whole burning with a slow fire, till the lime-stone is calcined. If any of the turfs fall down, they are to be returned to the clamp. The smaller the stones were broke, the more perfectly the lime will be burnt, and with the mixture of turf, coal, and wood-ashes, will make excellent manure.

Lime may be also burnt in kilns built with turf, the stones broke small, and laid in layers with coals, wood, or furze. These serve to burn lime occasionally, and in small quantities, These kilns soon decay, but the expence of erecting them is not much; and they may be made upon the fields where the lime is to be used.

But where there is a constant demand for lime, it is by much the best way to erect a kiln of brick or stone. Some are built wide at top, and narrowing downwards towards the bottom: but kilns of this form require much fewel. Such as are narrow at top and bottom, and wide in the middle, called reverberatory kilns require the least fewel, and burn the lime most perfectly; and where they are made not to be emptied at once, but some of the thorough burnt drawn out at bottom, and filled again at top, once or twice a day, these are called perpetual or running kilns, and are the most convenient, where large quantities of lime are wanting. The following I have found to be a good form for one of these kilns.

Pl. II. Fig. 7. *a, b*, is the depth of the kiln eighteen feet; *c, d*, the width of the kiln at the top, six feet; *e, f*, the width at bottom sixteen inches. The kiln at *g, h*, seven feet and a half from the top,
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is nine feet three inches wide, and continues of the same width to the middle at *i, k*. From the middle *i, k*, to the bottom *e, f*, it narrows gradually to sixteen inches: the form therefore of this kiln is somewhat elliptical or oval: from one hundred to one hundred and fifty bushels of stone-lime may be burnt in it every twenty-four hours; twenty bushels of coals or culm will burn about one hundred bushels of stone-lime, but considerably more of chalk-lime. The smaller the lime-stone is broke, the sooner it will burn to lime, and the more thoroughly. A kiln of this form reverberates the heat strongly, and will burn lime with much less fuel, than those that are widest at top.

It may be built of stone or brick, and the walls should be between two and three feet thick. If of stone, it should be such as will stand the fire, without being calcined; the blocks cut regular, and laid in strong mortar. If built with
bricks,

bricks, they should be of the best sort. But the violent heat will notwithstanding cause the stone and brick to scale and break off on the inside of the kiln; which, if constantly used will wear away so much, that the kiln, in no long course of time, must be rebuilt. To save in some measure this expence, the best way is to line such kilns at first on the inside, with the best bricks, laid flat all round it, with their ends pointing to the center of the kiln; and when these wear away with the heat, the whole brick lining is to be taken out, and the kiln new lined as at first: by this means the walls of the kiln will last a great while.

The best situation for such a kiln, is on the side of a hill, or rising ground, into which it should be built so far back, that only the eye, and a small part of the front of it should be seen, and all the rest sunk into the hill; being thus almost surrounded with a thick bank of earth, the
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heat will be confined, and less fuel will be necessary than if the walls of the kiln were naked and open all round.

When the kiln is thus erected, a good space of ground at the upper part of it should be levelled even with the top of the kiln, and a shed built there, large enough to receive the coals and lime-stone, and for men to work in the dry, and break the lime-stone there.

Kilns that are open and without shelter at top, are so much exposed to windy and rainy weather, that the burning is often obstructed, and sometimes entirely stopped by it; and much rain damages the lime. To prevent this, raise a dwarf wall all round the top of the kiln, except next the shed, where an opening is to be left, to fill the kiln when necessary; and the shed is to be continued quite over the kiln: which being thus sheltered on all sides, may be worked at all times without injury or obstruction from the weather.

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A cart-way is to be made, winding up the hill with a gentle ascent to the shed, that the lime-stone may be carried up there directly from the quarry without being unloaded. Or if there is not room for a cart-way, a narrow road may be made, to carry up the lime-stone and coals in wheel-barrows; but this is more tedious and expensive than to carry them up in carts.

Where there is a demand for large quantities of lime, a lime-house should be built adjoining to the eye of the kiln, into which the lime may be conveniently carried, as it is drawn out of the kiln, without receiving any wet: and is there kept dry, till it is wanted. This method of constructing a lime-kiln, sheds, &c. is the most convenient and complete, of any hitherto contrived.

Lime-stone-gravel is a manure of general use in Ireland, where it abounds. Some of it is also found in Britain, and might doubtless be found in many places,
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if diligent search was made for it. It consists of an earth mixed with small stones of different sizes, which are of a calcareous nature. If laid on the surface of meadow or pasture, the surface of the stones shell off in flakes with the weather, which dissolve and enrich the spots all round where they lie. This they continue to do every year till they are almost or quite dissolved, and all lands this manure is laid upon, are much enriched by it. It is a kind of stone marle, and greatly improves those estates where it is found.

Having thus considered the nature and application of the principal single manures, marle, chalk, lime, and limestone-gravel; it is unnecessary to extend our enquiries to other single manures of less extensive use; and therefore I shall here take notice of only one other kind, which is likewise pretty generally used, I mean soap-boiler's ashes; a manure recommended by the writers on this subject;

ject; but who have not distinguished the different sorts of it, though the difference is so great, that one load of the strongest will go as far as six or eight of the inferior sort.

To explain this, it is to be observed, that the soap-boilers in and about London, make use of the Spanish barilla, a kind of pot-ash imported from thence in serons or large lumps, very close, hard and full of salts. This the soap-boilers break and pound very small, and sometimes sift it, and being mixed with lime to open it, the salts are washed out: but the particles of the barilla are so hard, that some of them are not opened by the water, and a considerable proportion of salts remain still in the ashes. When these are mixed in a compost, the harder parts are opened by the fermentation, or by that and the weather, when carried to the land directly. Ten or twelve cart-loads per acre is a good dressing for cold strong land, which is much improved by
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them: but if laid on warm dry land, a much smaller quantity; or to be mixed with strong earth, or other cool manure, otherwise they are apt to burn such land.

Kelp made from sea-weeds is a kind of pot-ash used by soap-boilers. It is not so hard nor so full of salts as the barilla; it likewise makes a good manure, after they have done with it, but inferior to the former.

Another sort, very commonly used, is wood-ashes. These being open and spongy, their salts are readily washed out, so much, that they make a very weak manure. The farmer should lay on a much larger quantity of these than of the two former, or they will disappoint his expectations.

Another manure, that is for the most part used singly, or without mixture, is the dung of sheep, commonly laid upon the land in the way of folding. This is an excellent manure for all sorts of land; and so necessary where there are
extensive

extensive farms, consisting of large tracts of light dry lands, downs, heaths, and commons; that without the fold, the occupiers of those farms, which frequently lie at a great distance from large towns, could not cultivate their arable lands to any advantage for want of manure, in the common methods of cultivation. These light dry soils are commonly too poor to support large cattle, but are peculiarly adapted for sheep-walks. The short dry herbage is most agreeable to sheep, is excellent pasturage for them in summer, and while they feed there, they are not subject to the rot, and other distempers these tender animals are liable to, when kept upon low, rich, or wet grounds.

Summer folding has been found so advantageous, that some farmers are coming into a practice of winter folding their breeding ewes; a method too hazardous to be recommended or approved of. For though sheep attended by a careful shepherd, may be safely folded
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upon loams, and stronger land in summer, while the ground is dry and warm, it is very different in winter. The land is then generally wet and cold, and confining them in a fold upon such land during the snow or cold rains of that rigorous season, if it does not immediately kill them, will lay the foundation for the rot, and other dangerous diseases.

All sorts of cattle thrive best that are sheltered from the inclemencies of weather; and the method they have in Herefordshire, and some other counties, of housing their sheep in winter, is greatly preferable to winter folding. The best way for this, is to allow them a separate yard, made in the form above recommended, for a farm-yard, and sheds round it, with racks or cribs to put their hay in, or other food, as turnips, cabbages, cole-feed, &c. that they may feed in the dry, and have liberty of going into the yard at pleasure. The yard should communicate with, or be near to several small inclo-

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fures, of found dry pasture, to which they should have access in the day-time, and shut into their yard at night. Shifting them from one inclosure to another, will contribute to their thriving; for cattle in general love change of pasture, and none do so more than sheep.

The yard should be covered with good mould, and upon that some straw or dry fern, &c. by this means all the urine of the sheep, as well as their dung will be saved; and these layers of mould and straw may be repeated. A great deal of very valuable manure may be thus obtained, and will more enrich the land it is laid upon, than winter folding it.

The downs, heaths, &c. for sheep-walks, is of little value, otherwise than for providing manure to the other lands of the farm: for it is reckoned by the most skillful husbandman, that an acre of such poor land will maintain but one sheep, and that during the summer only: some indeed have stated two sheep, and others

other three to an acre; but this must be for very small sheep, or better land than common heath or downs. The late eminent husbandman, Sir Digby Legard, speaking of the Yorkshire wolds, says, "Our farmers stock nearly in this proportion, viz. a sheep for every acre; a flock of five hundred sheep requires a sheep-walk of five hundred acres, besides a winter's supply of fodder. These sheep are small, and when fat, weigh twelve or fourteen pounds per quarter; the fleeces weigh three pounds at a medium, which is scarce worth two shillings. Of the five thousand acres (belonging to that gentleman) uninclosed, upon the high wolds, there may probably be about five hundred acres in tillage. The value of the wool may be about five hundred pounds. I say nothing of the value of near one thousand lambs bred every year, nor of the encreasing value of the weathers and hogs, because the winter sustenance of the flock will be at least

an equivalent to the profit on those articles. The winter-keeping of the sheep will cost two shillings and six pence per head; and it is but too true, that the open wolds produce neither hay nor turnips. The sheep-fold is the only manure we have to depend on. Pigeon's dung is very powerful, and easily transported, but we cannot get enough of it to enrich much land. I keep about five hundred sheep, and can fold from May-day to Michaelmas thirty acres twice over."

According to this proportion, the manure raised from $8\frac{1}{3}$ acres of the wolds, is sufficient for but one acre of the arable land once folded; or if folding twice over is necessary, as it appears to be for this poor land, then one acre requires all the manure raised in five months, from $16\frac{2}{3}$ acres of the uninclosed wolds.

Again, the winter-keeping of the flock, cost two shillings and six pence per head in Yorkshire, where fodder is at a much lower price than in the more southern coun-

counties. Now, if it is considered, that the expence of winter-keeping is repeated every year, till the sheep are ready to be fattened or sold, together with the expence of a shepherd, casual charges and losses, it will appear, that the profits of the flock, and of the wolds, downs, &c. necessary for their keeping, consists principally, if not wholly, in what advantage can be made of the manure. More advantage, it is true, may be made by large sheep, but these cannot be maintained upon such poor land.

Considering therefore the hazard of winter-folding, that it may occasion the loss of some of the flock, and endangering the whole by the rot, and other contagious distempers, it is much the safest way, and the most profitable for the farmer, to house his sheep in winter as above-mentioned; by which he may be almost certain of preserving his flock in health, and high condition, and collecting a large quantity of excellent manure.

Besides the single manures, the farmer may have great advantage from composts; which, when they consist of proper materials, and are skillfully mixed, he may safely depend upon. Where a variety of materials can be had, they may be laid as follows; first, clay or strong earth, next soap-ashes, dung, loamy-earth, lime, tanners-bark, green vegetables before they run to seed, earth, soap-ashes, dung, tanners-bark, earth; or as many of these as can be got: also fat-chalk, seaweeds, sea-sand, and several others; which may be so mixed, as not only to raise a general fermentation throughout the whole compost; but likewise to suit the nature of the land on which it is intended to be laid. The common way is to lay the several materials in layers, one over the other, till a large heap is raised; and it is advised by some authors, and the practice of many farmers is, to make these layers from six inches to a foot in thickness: but this I have found by experience

ence is entirely wrong. For the fermentation raised in the compost, is not strong enough to penetrate these thick layers, especially those of clay or strong earth: for after the rest have sufficiently fermented, and the compost is turned, these layers rise whole almost as when first laid, and must be broke by hand to mix them with the rest of the compost; whence arise two inconveniencies, one, an extraordinary expence of labour, and the other, that twice or thrice turning is sometimes necessary to dissolve these large pieces; and as a new fermentation is excited every time the compost is turned, the strength of the manure is greatly wasted, before it is laid upon the land, where it is then incapable of raising any considerable fermentation, which is one of the principal uses of manure.

The best way therefore of making composts, is not in thick layers; but after the ground is marked out for the compost, the several materials, after being well

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broken,

broken, should be laid in heaps round the space marked out for the compost heap; and a man placed between each two heaps, to throw the manure spreading upon that space; In this manner the compost heap will soon be raised to the intended height, and the several sorts of manure being thus well mixed, the whole will soon begin to ferment, and will incorporate as fully in two months, as the same manures placed in layers in the usual way, will in four or five. The owner therefore in making such composts, should not prepare them too long before they are to be laid upon the land; otherwise they will be much wasted, and their best parts evaporated.

Composts prepared in this manner need not be turned, or at most above once. If the fermentation is observed to abate too soon, make holes with a pole, from the top almost to the bottom of the heap, upon which throw urine, or the running of a dunghill, which will fill the holes,
force

force through the whole substance of the compost, and soon complete the fermentation.

Such a compost, by duly proportioning the ingredients, may be made to suit any sort of land, and is excellent for meadow or pasture grounds. The best way to improve these, is to cut them about five or six inches deep with the five coultered cutting plough, or scarificator, which cuts the surface in slips about three inches asunder, but does not raise or turn them. This cutting of the roots of the grass, and the manure laid on at the same time, sinking into these incisions made by the coulters, causes a surprising improvement in the quality of the herbage, and also makes such grass-grounds produce three times the quantity they did before. But here it is to be noted, that cutting the ground first, and then laying on the manure, makes a greater improvement than manuring first and then cutting; and both are superior to manuring and not cut-

cutting; all which have been proved by accurate experiments. The cutting plough is used with great success upon clay-grounds, loams, and gravels; but in stony grounds, the coulter is apt to be thrown out of their work by the stones: and therefore it is not proper to use the cutting-plough where stones abound.

In such composts, where it is intended to use a large proportion of earth, that lies at a considerable distance from the homestead, to save the double carriage of it to and from the compost heap, the dung and other materials may be carried to a headland of the field to be manured, and there mixed into a compost.

The best situation for a compost, is upon level ground; or if made upon a descent, a trench should be cut on the lower side to receive the running of the heap, which is some of the best part of it, and should from time to time be thrown up again, which will quicken the fermentation.

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The richest composts may be made in the farm-yard, which should be made deepening all round, from the sides to the middle, in form of a hollow dish or basin. When the yard is made up in this form, none of the urine or liquid part of the manure can run off or be wasted. When the dung is carried from the stables, cow-houses, &c. into the farm-yard, they should not be thrown carelessly in heaps, each sort by itself, but carried in carts or wheel-barrows, and laid regularly, and spread all over the yard; upon this should be spread a thin layer of earth, mud, the scowerings of ditches and ponds, green vegetables before they run to feed, and other such materials as are most suitable to the nature of the land to be manured with them. The racks and cribs, out of which the cattle are foddered, should be frequently moved over the yard, that the offal, straw, and hay may be equally dispersed, and trod in by the cattle. This method
of

of spreading the dung and other materials being continued, the whole will be incorporated with the urine of the cattle, and make an extraordinary rich compost. Before it is carried to the land, throw it up in heaps in the yard, and what drains from them will remain in the yard, and none of it will be lost.

The only inconveniency of this kind of compost, is its being filled with the seeds of weeds, from the earths mixed with it, and the hay, straw, and dung of the cattle: and is therefore a manure best suited to grass-grounds, and to such arable lands as are to carry crops to be hoed, as turnips, cabbages, carrots, potatoes, beans, &c. as these weeds will in great measure be destroyed by good hoeing.

It is common with farmers to use several sorts of fine or powdered manures singly; as foot, malt-dust, rape-dust, peat and turf-ashes, saw-dust, lime, kelp and fern-ashes, pigeon and rabbits dung, &c. but it is still better to mix, as by

sifting or screening, as many of them together as can be conveniently procured. These make excellent hand-dressings for grass-lands, and clover, sainfoin, and lucern; also for wheat in the spring, turnips, and other crops; in all which they make a quick improvement. They recover crops that are drooping, and carry on others to perfection: for these dressings may be repeated several times in a season, at a small expence. The carriage is a trifle, and the trouble is only to sow it by hand over the crops. This is a very convenient manure, that may be used when none other can. The hard manures, kelp and fern-ashes, and also shells should be beat small and sifted; which the owner may have done for about a penny per bushel. This manure is particularly valuable in another respect. It does not make the land foul: for there are no seeds of weeds in it. Common salt has long been supposed to be a good manure, but the high duty upon salt prevented the farmers

mers making use of it. This objection is now removed ; for by an act passed the eighth of his present majesty, for the encouragement of agriculture, the duty is taken off foul salt, which is to be had at the salt-works, and is now sold in London, at four shillings per hundred weight, and by the ton at three pounds ten shillings. It has not, I believe, been ascertained what is the proper quantity to be used upon land ; but by the account of the sellers of this salt in London, the quantity for arable land, is between two and three hundred weight per acre ; and for lawns and grass-walks should be sown pretty thick, which will enliven the verdure. Sea-salt is however of so fiery a quality, that it is most advisable to begin with a moderate quantity, upon every sort of land, as the quantity may be encreased at pleasure, when the effect of it is known.

Many farmers are of opinion, that the land is apt to tire of one sort of manure,

long and often repeated, but here there is no danger of that. The whole is corrected by the variety in the mixture; and this manure is suitable to all sorts of land, or may be adapted to any, by varying the mixture.

Before I conclude, I shall take notice of some new manures proposed by Dr. Hunter, a gentleman to whom the public is obliged for his attention to improvements in agriculture. In consequence of his opinion, that plants are chiefly nourished from oily particles, he has proposed a manure which he calls, the oil compost, and directs it to be made in the following manner.

“ Take north American pot-
ash twelve pounds, costs — 0 4 0
break the salt into small pieces,
and put it into a convenient
vessel, with four gallons of wa-
ter. Let the mixture stand for-
ty-eight hours, then add coarse
train oil, fourteen gallons — 0 14 0

£. 0 18 0

In a few days the salt will be dissolved, and the mixture, upon stirring, will become nearly uniform.

“ Take fourteen bushels of sand, or twenty of dry mould; upon these pour the above liquid ingredients. Turn this composition frequently over, and in six months it will be fit for use.

“ When the liquid ingredients are put to one or two hogheads of water, a liquid compost will be formed, which must be used with a water-cart.

“ I apprehend, that the above quantity will be found sufficient for an acre; my trials, however, do not give me sufficient authority to determine upon this point.

“ The oil-compost is only intended to supply the place of rape-dust, foot, woollen-rags, and other expensive hand-dressings. It is in all respects inferior to rotten dung: where that can be obtained, every kind of manure must give place to it.

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“ My experiments teach me, that all kinds of soils may be benefited by this manure. The lime-stone, gravelly, sandy, and chalky soils seem to require it most. The rich loams and good clays have nourishment within themselves, and stand more in need of the plough than the dunghill.”

The doctor likewise very justly recommends as a rich manure, the refuse of train-oil, viz. what remains after the oil has been got from the whale-blubber by boiling water, and has hitherto been thrown away. “ No manure, says he, has hitherto been found of a richer quality than the putrid offal of fish. In some parts of Cornwall, they manure their lands with pilchards, in a plentiful season, and find that no manure equals them in richness.”

Another very good compost recommended by this gentlemen, is made as follows: take a sufficient quantity of

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saw-dust; incorporate with it, the blood and offal of a slaughter-house, putting a layer of one and a layer of the other, till the whole becomes a moist and fetid composition. Two loads of this compost, mixed with three loads of earth, will be sufficient for an acre of wheat or spring corn. Being a kind of top-dressing, it should be put on at the time of sowing, and harrowed in with the grain. If the smell of this compost should be offensive, it may be prevented by sprinkling quick-lime between the layers, when the compost is made.

All these are very good manures, and the only objection to them, is, that they cannot be of general use, being to be had only in particular places.

I have said nothing of liquid manures, to be spread upon land with a water-cart, as a top-dressing; as the powdered manures above-mentioned answer the same purpose with advantage. The liquid
manures

manures require a water-cart, and to be drawn by a horse, which is prejudicial to the land, and the hot quality of them injurious to the tender young plants. The powdered manures do no hurt in this respect, if sown upon the crop in dry weather, and the first shower of rain washes them down to the roots of the plants, the good effect whereof is soon perceivable from the flourishing state of the crop.

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FOR MARCH 1882

THE following is a list of the names of the persons who have been admitted to the membership of the Society since the last meeting of the Executive Committee, held on the 15th of January 1882.

1882

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MISCELLANEOUS
DISSERTATIONS
ON
RURAL SUBJECTS.

The principal drill-ploughs hitherto made.—

Of Mr. Tull's drill-plough; a general description of it.—Improvement of it by the author.—Of the other principal drill-ploughs, and their defects.—Description of a new and important improvement of Mr. Tull's drill-plough.—The barrel-drill improved, and made a general instrument, to sow all seeds, and at any distance.—Of drilling corn for horse-hoeing, hand-hoeing, and close drilling not to be hoed.—Objections to drilling answered.—

Experiments of drilling and hand-hoeing of wheat.—Experiments by Mr. Tull of horse and hand-hoeing of wheat.--His improvements of the hoeing husbandry.—The successful practice of the hoeing husbandry exemplified.—The expences and profits of that husbandry.—Several objections to the hoeing culture considered and answered.—

Of the alternate husbandry.—The produce and expence of this method compared with the hoeing culture.—The ancient method of alternate cropping and fallowing.—Examples of this culture.—The same compared with the alternate and hoeing culture.

ON DRILL-SOWING.

THE most intelligent husbandmen have long been of opinion, that the common method of sowing corn and other seeds with the hand, or broad cast, was attended with considerable loss in the waste of seed, and often an injury to the crop, by the irregular distribution of it, which in promiscuous sowing is unavoidable, as the seed cannot in that manner be laid at equal distances, nor at any certain depth; but were obliged to continue that practice, not knowing any way of distributing the seed more equally.

It is above a century ago, that some attempts were made, to invent an instrument for planting the seed in a regular manner; and hence the Spanish sembrador,

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dor, Platt's setting-sticks, and Worlidges' proposed drill-plough, the last of these was never brought into practice, and the others were found inadequate in the performance. The first instrument that really answered in practice, was the drill-plough invented by the famous Tull, with which, for a long course of years he planted sainfoin, pease, wheat, barley, oats, and turneps.

He adapted his drill to plant wheat in double rows, upon small ridges about four feet eight inches broad, for the purpose of horse-hoeing the intervals between the double-rows; the narrow partitions between the rows on the tops of the ridges, which were ten inches asunder, he cleansed from weeds by the hand-hoe, and the rows were hand-weeded. As the staple of all sorts of land is full of the seeds of weeds, this accurate tillage greatly encourages them to grow, and unless they are carefully eradicated before they run to seed, they multiply, and greatly

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greatly damage the crop; for this reason he made his land very clean at first, and before he began drilling it, by good fallowing and hoed crops of turneps, and afterwards kept it so by hoeing and weeding; till at last he says, p. 274.

“The same six score acres that was wheat the last year, is planted with wheat now, and is all of it as strong, and likely for a good crop, as any of the former years, though there is but about one acre of it dunged. The whole of it is the freest from weeds before hoeing that ever was seen, and the sown wheat in the neighbourhood the fullest of them.”

The ridges to be drilled are made straight, and all of an equal breadth, the tops of the ridges should be made smooth by a couple of light harrows fastened together with a pole, the horse that draws them walking in the furrows between the ridges. This done, the drill-plough is drawn by a little horse, along the middle of each ridge, where it opens two channels

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nels about two or three inches deep, and ten inches distant, into which it delivers the seed, and covers it. In this manner it plants six or seven acres a day, with about three pecks of seed per acre, but if planted early upon good land, about two pecks per acre is sufficient.

Few farmers can believe, that two or three pecks of seed-wheat will produce as good a crop per acre, as so many bushels sown broad-cast. Or that two rows upon a ridge of four feet eight or nine inches broad will produce as much as the whole ridge covered with plants, not considering the number of tillers that spring from the drilled, more than from the broad-cast; the large size of their ears and grains, and the great number of grains in the ears; for an encrease of ten or twelve bushels for one sown broad-cast is reckoned a very good crop, whereas the drilled often produces thirty, forty, or fifty times as much as the seed planted.

To

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To give a general idea of the structure of this instrument, Pl. II. fig. 1. is Mr. Tull's drill-plough, with his latest improvements, *a, b, c, d*, is a plank, to which the shafts, *e, f*, are fastened, and by these the horse draws the whole machine, the rings at the ends of his traces being put upon the hooks at *h, h*. The spindle *g, k*, is drawn by the two double standards fixed into the ends of the plank, and the two wheels and spindle turn round together. The spindle is in three pieces, grafted together at *m* and *n*, fig. 2. and the middle graft *m, n*, has two sets of notches cut in it, at *o* and *p*, each set has six notches cut in it round the spindle, at equal distances, *m, n*, fig. 1. is the hopper, made to hold about two pecks of seed, half at each end, the hopper being divided in the middle by a board. The hopper is held to the plank, and drawn along with it by the standard *o*, which passes through a latch behind the hopper. To the bottom of the hopper the two seed-boxes are fastened.

These

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These have large round holes in them to receive the spindle, which turning round with the wheels, the notches lay hold of the seed, that falls from the hopper into these boxes, and bring it down in equal proportions, and it falls from the seed-boxes, close to the backs of the two shares *gg*, till it reaches the bottom of the channels, in the ground just opened for it by the shares. The rope *r, t*, at the fore-end of the shafts, goes over the cart-saddle, and has a small chain with a hook at one end of it, *r*, by shifting the links of the chain upon a hook fastened in the shaft, at *s*, the shafts are raised or depressed, which regulates the depth of the shares in the ground, and makes the seed-channels deeper or shallower at pleasure.

The harrow *u w*, is fastened to the hinder end of the plank, and moveable at *x* and *y*. In the harrow are two tines *t* and *t*, which are some inches farther asunder than the seed-channels. These tines raise and turn the mould into the channels,

channels, which covers the seed, and finish the operation.

This drill-plough performs very well, in land brought into good tilth as I have experienced. There is, however, scarce any mechanical invention that does not admit of some improvement. Most of Mr. Tull's land was a light soil, and he made his drill suitable to it, very light and easily drawn. In stronger land, a drill-plough of greater strength is more convenient, and indeed necessary; and likewise some contrivance to manage and guide it steadily. To answer these purposes I made some alterations, particularly the following.

The long shafts are taken away, and in their room are put two strong ones, or sides-pieces, extending about as far forward as the cross bar *pp*, and the fore ends elevated as high, (*i. e.* as the cross bar was before); those have each a hook at the fore-end, upon which are put the rings of two hempen traces, by which the horse draws the drill. Two handles,
like

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like those of a common plough are likewise fixed to the hinder part of the plank, which serve to guide the drill, and to regulate the depth of the seed channels: by leaning upon the ends of the handles the shares are made to go deeper, and the contrary if the handles are raised.

If the land when drilled is dry and fine, the mould will run into the channels and cover the seed with little or no harrowing; but two iron tines are commonly used in the harrow, and more if the land is rough; for the seed, should be all covered, and the harrow is fixed and does not extend so far behind the drill, as in Mr. Tull's. His harrow was made moveable, that the tines might rise over any clods that happened to lie in their way. But by their rising, some part of the ground is missed by the harrow, and the seed left uncovered. To remedy this, he sometimes loaded the hinder part of the harrow with a stone at z ; but this is not necessary when the harrow is fixed,

by which means, and the conveniency of handles to guide the drill, the clods are broke by the tines, or turned aside.

A person who understands the fabric of his drill feed-boxes, can set it by his eye, so as to deliver nearly the quantity of seed he intends to sow upon an acre; but at first it is necessary to adjust it, before he begins drilling.

A statute acre is forty perches in length and four in breadth, five yards and a half to the perch; and the area is one hundred and sixty square perches. Now as there are fourteen of Mr. Tull's ridges in the breadth of an acre, or four perches, and two rows of wheat planted upon each ridge; in the breadth of an acre therefore there are twenty-eight rows, each row forty perches, or two hundred and twenty yards long, which, if planted with six gallons of seed, at $7\frac{1}{2}$ pounds per gallon, is forty-five pounds of seed to all the twenty-eight rows, and one pound and near ten ounces of seed to each row,
three

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three pounds four ounces to the double row.

To adjust the feed-box to sow this quantity, proceed as follows. Upon some level ground set up a mark, and place the drill there, having filled the hopper about half full of the wheat to be planted; from the drill-measure streight forward eight perches, or forty-four yards, and there set up another mark. Then drawing the drill gently forward, from the first to the second mark, the notches in the spindle will turn out the seed as the drill goes on, which is to be received in two small bags or boxes placed under the feed-boxes for that purpose; and when arrived to the second mark weigh the seed thus saved; and if each box has delivered $5\frac{1}{5}$, or near five ounces and a quarter, the boxes are set right, and need no alteration. For $5\frac{1}{5}$ ounces of seed delivered in eight perches length of rows, is nearly forty-five pounds to all the twenty-eight rows; which was the quantity proposed

to be planted. But if the quantity delivered by one or both the boxes is wrong, open or contract the feed-passages a little by the regulating screws, and draw the drill from the second to the first mark, and weigh again what seed is turned out; by a very few trials made in this manner, the feed-boxes will be adjusted to the quantity required.

This may appear troublesome at first, but will become easy by a little practice, and the advantage is very considerable. I have drilled fields of five or six to above twenty acres, with wheat, barley, oats, and pease, and adjusted the drill so near, that the seed remaining over and above the intended quantity, has not exceeded half a bushel in drilling twenty acres; and nearly in proportion in drilling smaller fields.

The quantity, indeed, would not always have been so exact, from the first adjusting of the drill; but there is another circumstance that contributes to it.

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The hopper being divided in the middle with a board, the driller may see at all times whether the two feed-boxes deliver the seed equally, by the equal emptying of the two divisions of the hopper; and if they do not, they are presently adjusted by the regulating or setting screws.

Another way of drilling wheat and other kinds of grain, is upon level ground, or broad ridges, in rows about twelve inches distant, and hand-hoed. Most farmers much prefer this method to horse-hoing; and in general it produces better crops than the broad-cast, and the hoeing cleanses the lands from weeds, and much improves it for the succeeding crop. The saving of seed is a great advantage in this method also; for a bushel of wheat is sufficient to sow an acre.

But in this manner of drilling, the drill-plough with only two shares is not convenient; requiring too much time to plant any considerable extent of land, with

with but two rows each draught, and so near together as twelve inches. A drill that sows four rows at once is the most proper, and for this four seed-boxes, and the same number of shares are necessary. As this drill sows only four feet breadth of ground at once, it does not plant so much land as that for horse-hoing, by above an acre a day, but should not be made to plant more than four rows at that distance; for it is found inconvenient in practice, to drill a greater breadth of level ground at once than four feet.

In planting wheat to be horse-hoed, the driller cannot mistake the distance of the rows, the ridges being his guide in that respect, and in making the rows straight. But in drilling upon level ground, he must have some marks to direct him, to make the parting-space between every four rows, a foot wide all the way, the same as the spaces between the rows made by the drill. The wheels serve for this purpose; for being made to slide upon

the square ends of the spindle, which has several holes bored through them; and the wheels, being set to the proper distance, are confined there by two small iron pins, one at each end, made long enough to pass through the spindle and iron stock-bond of the wheel.

To place the wheels for marking, they should be set twice as far asunder as the breadth of the land planted by the drill. Thus in the present case, the drill plants a breadth of four feet; and therefore the wheels should be set at the distance of eight feet, each wheel four feet from the middle of the drill; which being drawn along, the wheels make two small impressions upon the surface of the ground, upon one of which the horse walks in returning, and drawing the drill directly after him, four more rows are planted, whereof that next the first planted will be twelve inches distant from it, and thus every turn, the horse-path is upon the preceding mark of the wheel; and in this manner

manner the whole field will be drilled in rows so nearly equidistant, that the parting-spaces are scarce distinguishable from the rest.

If the land is dry, as soon as it is made pretty fine by the harrowing, draw a light roller over it to break the small clods, and then the impressions made by the marking-wheels will be plainly seen; or harrow the field the last time across the intended track of the drill, and in this way also the wheels will make a visible impression, sufficient to guide the horse; which they will not do, if the drill is drawn in the same direction as the last harrowing.

The twelve inch spaces must be hand-hoed: if hoed the first time early in the spring, twice is generally sufficient; and sometimes but once, if hoed late. But the number of hoeings are to be such as to keep the land clean, and there is no loss, but the contrary, in giving the land a hoeing extraordinary, though there are

but few weeds in it. But if the rows are drilled at the distance of twenty or twenty-four inches, the intervals may be hoed deep with a hoe made on purpose, and drawn by a horse; and the rows should be earthed up on both sides at the last hoeing. This will likewise produce a good crop, and at a less expence than hand-hoeing.

There is another method of drilling upon level ground, that does not require any hoeing. The rows are about seven inches distance, and if the land is very clean, may be eight inches asunder. When wheat is drilled in this manner, and advances in the spring, the rows spread and meet, and keep down the weeds. A bushel of wheat sows an acre; and the crop is generally superior to that sown broadcast on the same land, with the usual quantity of seed.

A drill to sow in this manner should have five or six shares, and plant so many rows at once: but the shares should be in two ranks to sow the rows so close as seven inches,

inches, otherwise they will drive the mould in heaps, and obstruct the regular sowing, unless the land is extraordinary fine and clean. This method of planting is called close-drilling, and is proper for wheat, barley, and other grain : I have drilled barley in this manner with success. But barley is not fit to be sown in wide distances, that require either to be horse or hand-hoed ; because the hoeing causes it to throw out many tillers or branches, at different times throughout the summer, and then the barley ripens unequally, the late tillers being green at harvest when the rest of the crop is ripe, which lessens the value of it at market, as it is not fit for malting. This misfortune happens sometimes to barley sown broadcast, particularly to such as is sown in a very dry season ; for then the grains that happen to lie deepest in the ground spring up without rain ; but such as lie near the surface do not till rain comes. The first by this means gets a-head of the other, sometimes

several weeks, and in that case the crop is never all ripe together, but is what the farmers call edge-growed, and when this happens is a great loss to them. There is besides another inconveniency in it, the unripe part of the crop, is apt some years to ferment in the stack or barn, and then the whole is mow-burnt. This is to be understood more particularly of barley that has no clover among it, and where it grows rank, and is reaped.

In the latter part of Mr. Tull's practice, he made his drill-boxes of brass, which is best; but boxes made of box or other close hard wood do very well, and are cheaper than brass. The middle graft of the spindle of the drill-plough, in which the notches are cut, should be made of sound dry heart of oak; the other two parts may be of quartered ash, or beech.

With the wheat-drills may be planted barley, oats, rye, and such sized corn; also pease, vetches, buck-wheat, and fain-

fainfoin. But larger boxes are necessary to plant beans; and for turnep-seed, and other such small seeds, the boxes must be much smaller than those for wheat. So that those who would drill extensively, should have three different sorts of drills, proper for planting the different sized seeds above mentioned.

Some who did not understand drilling, or were prejudiced against it, have objected to the slightness of Mr. Tull's drill-plough, an objection that may be removed by the above-mentioned alterations, by attending to which, an ingenious workman may so strengthen every part, as to make this drill-plough perform its work, with as little danger of being out of order, as some of the common instruments of husbandry.

The difficulty of using the drill is another objection made to it; and it is admitted, that the owner should understand its fabric, so as to be able to repair, or put it in order, or direct a workman to do

it, when any thing is amiss : but in regard to the management of it in drilling, there is very little difficulty. A prime seedsman in the broad-cast way, will not indeed, be easily prevailed with to use a drill; but any inferior servant employed about a farm, who has some ingenuity, and is tractable, will very soon learn to use it, as it puts him upon an equal footing with the best seedsman. I have taught some such to use a drill-plough, that in two days practice have been so expert in the management of it, as to go on very well without farther assistance; and the seedsmen, who before slighted a drill-plough, seeing with what regularity it planted the seed, have desired to learn how to use it.

Since the time that Mr. Tull published his husbandry and instruments, several ingenious persons have invented drill-ploughs of different constructions from his. One of the first was M. de Chateauxvieux, first syndic of Geneva, whereof Mr. Mills,

Mills, in his Husbandry, has given cuts and a description. It is a curious instrument, but complex and expensive, and constructed to sow only three rows at seven inches distance. Mr. Mills has omitted to describe Mr. Tull's drill, supposing it to be more complex than the other; but by mistake, he not being experienced in the practice.

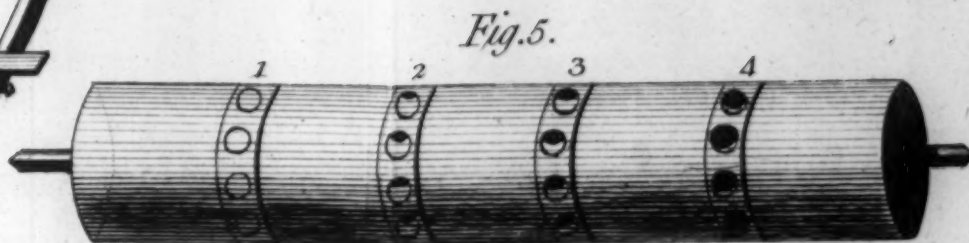
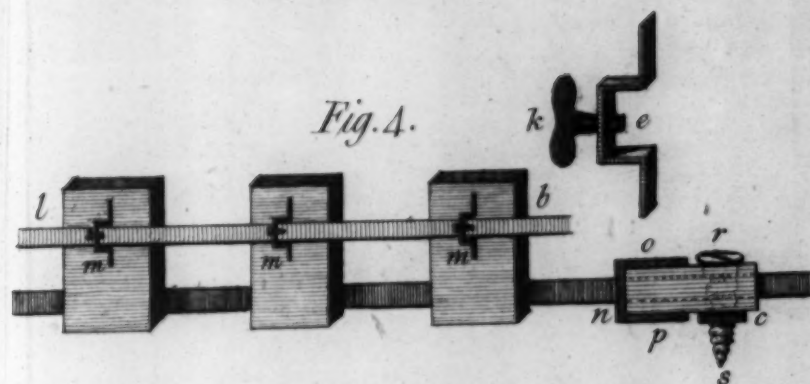
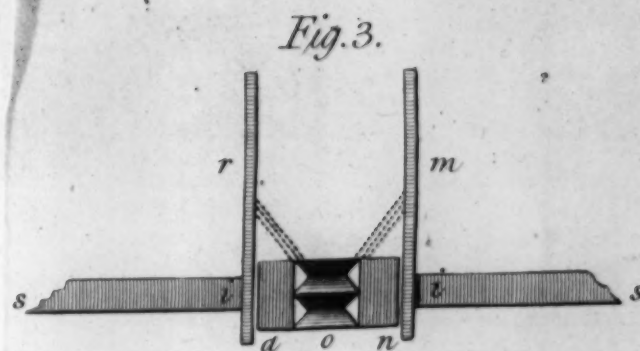
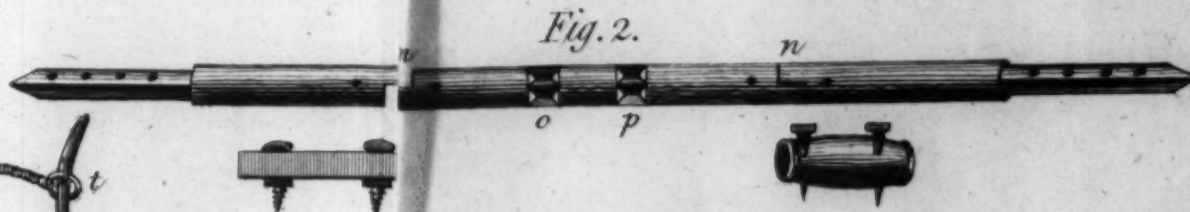
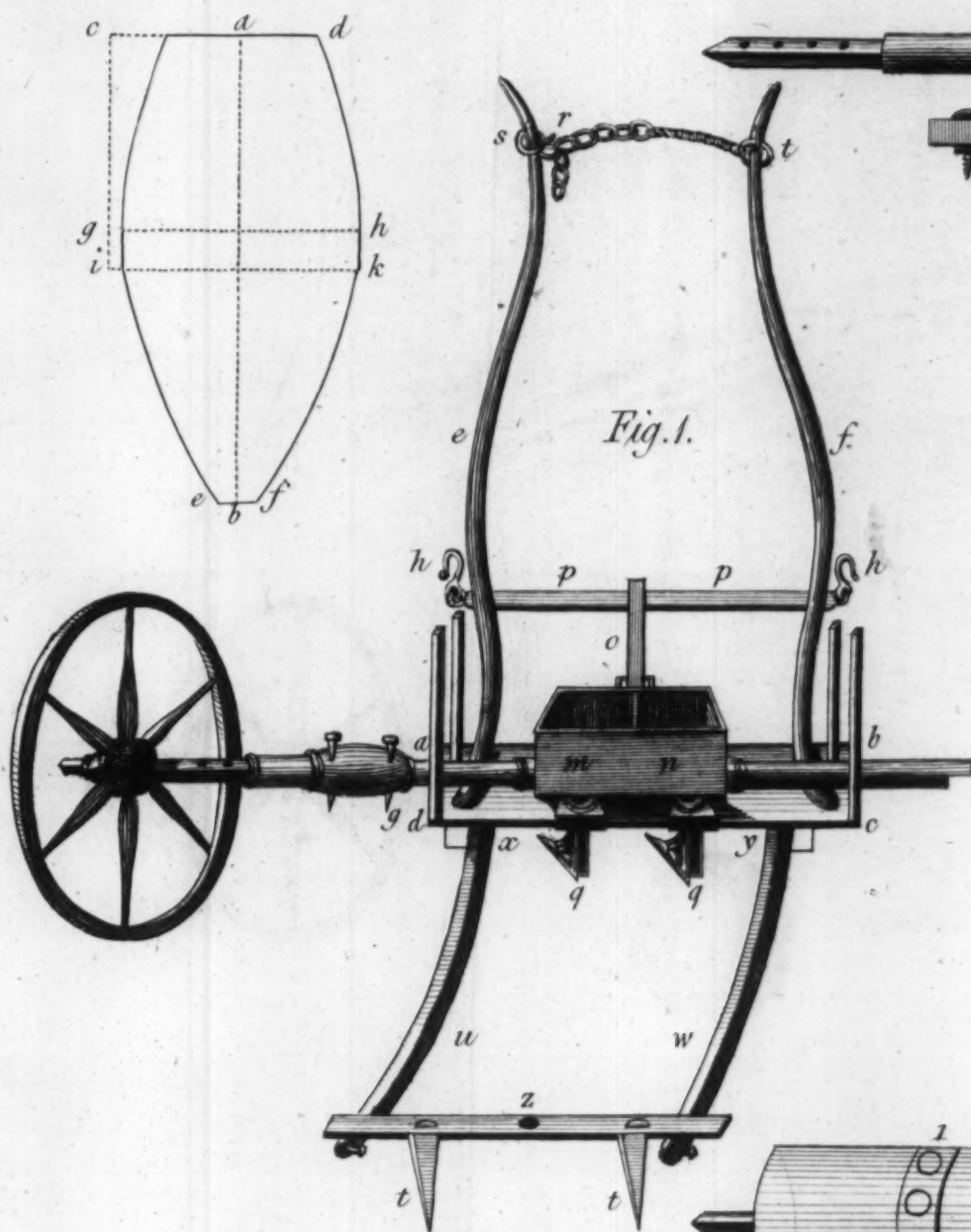
About the same time another sort of drill-plough was invented by M. du Hamel, called a barrel-drill, of which more afterwards. This drill has been introduced into Britain and Ireland, first by Mr. Craik, near Dumfries, in Scotland, a very ingenious practiser of the new husbandry, who has made some material improvements on Mr. du Hamel's drill; and since that, Mr. Wynn Baker has made barrel-drill, whereof the construction was taken, as I am informed, from Mr. Craik.

Mr. Randall, of York, has invented another of a very different construction
from

from either of the former, the performance of which I am unacquainted with. And Mr. Baldwin, of Clapham, in Surry, has constructed one upon the principles of Mr. du Hamel's, and to plant more rows at once.

These are the principal instruments for regular sowing, that have come to my knowledge, all which are defective in one particular; they are limited to sow at certain stated distances, from which they cannot be altered. I had a drill made to sow six rows at once at six or seven inches distance, but that was likewise confined to that distance, from which it could not be altered; but since then, I have contrived a method, by which either Mr. Tull's, or the barrel-drill, may be made to plant from one to six rows, and the rows from seven inches to four feet distance, whereof the following is a description.

Plate II. Fig. 3. *a, n*, is a piece of sound dry oak, perforated lengthways through
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the middle, by a hole three quarters of an inch square, upon which turn it in a lathe; the parts *a* and *n* to be $1 \frac{5}{8}$ inch diameter, or of a size to fit the hole of the drill-box. This round piece of oak represents a portion of the middle graft of the spindle of Mr. Tull's drill-plough, with six notches cut in it at *o*, the same form and size exactly as in that spindle. The square hole made through the middle of the piece, is to receive an iron spindle *s s*, $\frac{3}{4}$ of an inch square to fit that hole, so as it may be moveable on the spindle end-ways, but not to turn round upon it.

A hopper is to be made of elm or walnut-tree six inches wide within, one way from *r* to *m* and eight inches the other; the bottom of the hopper to be of inch-board, and the sides of half-inch. The two sides *r*, *m*, are to be made deeper than the others, with holes in them for the spindle to pass through at *i*, *i*. The seed-box is to be the same as the seed-boxes of Mr. Tull's

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Tull's drill, of brass or box-wood, and fastened with screws and nuts to the bottom of the hopper, through which there is a hole made for the seed to pass into the feed-box.

The notches or piece of oak, *a, n*, being put into the feed-box, and confined from moving end-ways by the sides of the hopper at *i, i*, run the iron spindle through the square hole of the notches, by turning which round, the seed will be brought down by the notches, and delivered into the feed-channel, close to the back of the share. Thus one hopper, and feed-box are completed for sowing one row; and in the same manner six of them are to be made, all to be put on the iron spindle; and as they are made separate and independent one of another, and all to slide upon the spindle, they may be set to the exact distance required.

The iron spindle is six feet long, whereof $4\frac{1}{2}$ feet is for the feed-boxes and hoppers to slide upon, and nine inches at each end

end is to go into two round grafts of wood two inches diameter, and makes the whole length of the spindle about ten feet. To strengthen the wooden grafts, and prevent their splitting, they have caps of iron as *o*, *n*, *p*, figure 4 and $\frac{3}{4}$ inch square holes at their ends, as at *n*, where the iron spindle enters; and the ends of the iron spindle are confined as at *r*, *s*, by two iron pins with screws going through them and the wooden grafts, and fastened with nuts as at *c*. The other ends of the grafts are made square, for the wheels to go upon.

When all the six seed-boxes and hoppers are put upon the spindle, this drill sows six rows at once seven or eight inches distant; but to sow at greater distances, one or more of the hoppers are to be taken off, and then it will sow them wider, but not so many rows. Thus suppose three are taken off, the three remaining will sow three rows at sixteen inches asunder, or at any other distance from seven to
 sixteen

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sixteen inches. Four will sow at any distance, from seven inches to twelve, &c. and the same drill will sow double rows upon ridges for horse-hoeing.

To confine them to the distances intended, small iron staples, or of wood like the carrier of a latch, as *m, m, m*, fig. 4. are fixed to the back of the hoppers, one about the middle of each box, or one above and one below in each; and laths *l, l*, being thrust through these staples, the boxes slide upon them, and are fixed to the proper distances, by small screws with T heads, as *k*, going through one or more of the staples in each box: the ends of the screws made flat and rough as at *e*, and pressing against the laths, will confine the boxes from sliding. These laths also strengthen the iron spindle, and prevent its bending.

M. du Hamel's drill above-mentioned, consists of a wooden barrel with three rows of holes round it, six or eight holes in each row; a spindle passes end-ways through

through the middle of the barrel, with a wheel at each end. A small part of the barrel, near the whole length of it, turns upon a hinge, and opens to put in the seed, and is shut when the barrel is near full. It was made thus at first; but since Mr. Craik's improvement, the holes in the barrel are big enough to pour the seed through into the barrel. As the wheels turn round, they turn the spindle and barrel, and the seed drops through the holes close to the back of the shares in the seed-channels made by them: but one great difficulty remained, viz. to regulate the size of the holes, so as to discharge the proper quantity of seed.

This Mr. Craik has removed, by making the holes in the barrel large enough for many seeds to pass through at once, and regulating the quantity by the moveable hoops of tin, made to surround the barrel, and cover the three rows of holes; and these hoops having the same number of large holes in them, and at the same

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distances as the holes in the barrel, by sliding the tin hoops round, they cover the holes in the barrel and prevent any seed from running out of it; or by bringing the holes in the tin-plates, to those in the barrel, openings are made for the seed to pass, larger or smaller as the driller finds necessary to discharge the intended quantity of seed. The quantity to be sown upon an acre being determined, this drill is to be regulated to sow that quantity, in the manner above described for Mr. Tull's drill. This is an excellent improvement; for by this contrivance, any quantity of wheat or other grain may be sown, from one or two pecks to several bushels upon an acre. And what greatly recommends this method still farther, is, that this drill sows seed of all sizes from the largest beans to turnep-seed, both inclusive. Carrot-seed may likewise be drilled with this instrument thus improved; the carrot-seed being first rubbed through a fine wire sieve to

to take off the hairy ends of it; for without that preparation the seeds stick so together, that they cannot be sown very even, by any instrument, nor by hand. Mr. Tull's turnep-drill sows such very light seed best; because the notches in the spindles of his drills lay hold of the seed, and bring it down regularly, whether it be heavy or light; and in this respect his is superior to all other drills, that have any dependence for their regular sowing upon the weight of the seed.

This is plainly seen in the drill now under consideration. M. du Hamel did not observe, that the seed run through the holes of the barrel unequally, viz. not so fast when it was full as when it was near empty. This the very accurate Mr. Craik discovered in using his barrel-drill, and that the seed run out slowest when almost full, and gradually faster as it emptied. He likewise invented a method of filling the barrel, whereby it was kept constantly so equally full, that this

inconveniency was remedied ; to accomplish which required, however, so much machinery, that the price of his drill is considerably advanced by it. Pl. II. fig. 5. is the barrel-drill ; 1, 2, 3, 4, are slips or collars of tin-plate, made to slide in four shallow grooves or channels cut round the barrel ; each plate has eight round equi-distant holes in it, about half an inch diameter each, corresponding with round holes in the channels of the barrel, of the same size and number in each channel. By sliding the tin-plates upon the barrel, the holes in them may be brought to stand against those in the barrel, and then, in turning the barrel round, a large quantity of seed would be discharged, much more than is commonly necessary ; and by sliding the tin-plate, so as to cover more or less of the holes in the barrel, more or less seed will be discharged : or the holes in the barrel may be wholly covered with the plates, and then no seed will run out.

It seems at first view somewhat unaccountable, that the seed should run faster out at the holes of the barrel when near empty, than when it is full; but the reason is, that when the barrel is full, the seeds at the holes are pressed by the weight of those above in a greater degree than when there is a smaller quantity of seed in the barrel, and the pressure gradually lessens as the barrel empties. The pressure causes the lowermost seeds to run closer together at the holes, and by that means they obstruct one another in their passage, forming a kind of arch there; the more they are pressed, the greater is the obstruction, as it is when the barrel is near full, and the obstruction is consequently lessened as the barrel empties, and the pressure lessened.

To regulate therefore the delivery of the seed, the pressure is to be abated, and this may be done by different methods; the following is a cheap and ready way. On the inside of the barrel fix laths, or

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thin

thin boards about two inches broad, and the length of the barrel, to which the boards are to be fastened at one edge, as at *a, b, c, d*, Pl. II. fig. 6. and the other edge at a distance from it in a sloping position. The number of these boards should be the same as the number of holes round the barrel: as suppose eight holes are made round the barrel to sow each row, then eight of these small boards are necessary, to be placed over the holes, in the above mentioned oblique position. Every row round the barrel should have the same number of holes at equal distances in the circumference of it; and they are to be made in streight lines lengthways of the barrel. Being made in this regular manner, each of the thin boards will stand over one hole in each circumference.

In drawing the drill forward to sow the seed, the wheels and barrel turn round always the same way, as from *a*, to *b, c, d*, fig. 6. and in fitting on the
long

long narrow boards over the holes, the edges of them that are fixed to the barrel should be on the rising side of it, as at *a, b, c, d*; by placing them in this manner, they prevent the perpendicular pressure of the seed at the holes, and at the same time permit the seed to come to the holes, where the pressure is small, and only lateral.

This contrivance serves to regulate the discharge of the seed, where two or more rows are sown out of the same barrel, and at certain distances not to be altered. But a drill to sow the rows at different distances, should have short barrels, one for each row, with six or eight holes round the middle of it, to deliver the seed. These short barrels have a spindle of iron or wood, that passes through the middle of each, and upon which they slide endways. It is not necessary that the middle part of the spindle to these barrels should be made of iron, as in the drill above mentioned: but for these barrels,

rels, the whole spindle may be made of wood, and grafted in two places as the other. The barrels are confined to the required distances by laths, in the manner directed for the boxes in the other drill, and the other parts are nearly the same in both.

As this drill-plough sows all the seeds of different sizes, commonly sown in the fields, and plants the rows at any required distance, it may be accounted an universal instrument, excelling all the drill-ploughs that I have mentioned above, or have any knowledge of. They all being limited, either with respect to the size of the seed, or the number and distance of rows to be planted.

I have already observed that the farmers are in general prejudiced against the manner of drilling wheat for horse-hoeing; they are accustomed to sow much seed, to see the plants come up thick and cover the ground, and cannot believe that two rows only, drilled upon a ridge four feet

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feet eight or nine inches broad, will produce half a crop. They look upon the empty spaces between the rows as so much ground lost. They are, however, more reconciled to the manner of drilling in single equi-distant rows for hand-hoeing; and several have in different places, adopted that practice for wheat and other sorts of corn.

Nor is it the common farmers only who object to wide spaces for horse-hoeing, but others also, of larger ideas, have supposed them unprofitable, and that good crops are not to be expected from them. Among these I am sorry to find one gentleman, the author of the Complete English Farmer, condemning that method, whose censure may deter others from giving it a fair trial, especially, as he says, he was acquainted with Mr. Tull, and his husbandry. In order to have a full view of his objections I shall recite them.

In the preface p. 15, he says, " That the destruction of weeds, the multiplying of fibres, and the loosening earth about the roots of plants will encrease their vigour, are truths that cannot be controverted ; but in this country where labour is dear, the expence of performing these operations, I am inclined to think, from my own little experience, will exceed the profit. Will any one, who has made the experiment, take upon him to say, that in rows only twelve inches apart, the two inches that are planted will produce an equal quantity of grain, after being three times hand-hoed, with the whole fourteen inches planted in the ordinary manner, provided the land is all equally prepared, with an additional excess, that will pay for the excess of labour.

" In the horse-hoeing culture, though the expence of labour may be less, the waste of land is out of all proportion greater ; for there, only four inches out of seventy-two are planted, the remaining

sixty

sixty-eight are left for the introduction of the hoe-plough. And will any one say, that in the nature of things, four inches can be made to produce as much grain as seventy-two, provided the whole seventy-two are all in the same heart before planting? From my own experience I am inclined to conclude they will not."

As to the supposed waste of land in the horse-hoeing culture, it is admitted that Mr. Tull for some time, drilled two rows of wheat upon six feet ridges, which is only four inches planted in seventy-two; but the author should have taken notice, that upon fuller experience, he planted two rows upon ridges only four feet eight or nine inches broad, which is four inches in fifty-seven. But not to insist upon this, the author has answered his own objection, and acknowledges that four inches drilled in seventy-two may produce as large a crop, as the whole seventy-two sown broad cast: for, p. 213 he informs us, "That Mr. Tull had of-

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ten upon two rows in six feet lands, at the rate of five quarters of wheat on an acre." And this, I suppose, all farmers will admit is a very good crop, not often obtained upon the whole seventy-two inches sown broad-cast.

It is from hence evident that the spaces between the rows is not a loss of so much land; but being well cultivated by the horse and hand-hoeing, and kept clean from weeds, are in the nature of a fallow, and the land not only produces a good crop, but it is also at the same time so much enriched by this culture, as to produce another good crop the following season without manure, and continues so to do every year, so long as this culture is continued. Mr. Tull demonstrates this by his own practice for a course of thirteen years, and the same has been since confirmed by the experience of others, and by some for a much longer time.

It seems surprising that any practical husbandman acquainted with drilling, should

should suppose that twelve-inch spaces will lessen the crop; or that it is contrary to the nature of things, to obtain as good a crop by the horse-hoeing as is usually obtained by the common husbandry. I shall produce some instances in both cases, which proves this to be practicable, premising one from Mr. Young's account of Mr. Scroope's experiment-field, in Yorkshire. "In the year 1766, Mr. Scroope, in his experiment-ground, drilled many sorts of garden plants, in single rows, four feet asunder, horse-hoed thrice, besides hand-hoeings and weedings. Onions, celery, endive, garden beans, coss lettuce, cauliflowers and artichokes, all proved incomparably good; and not only sweeter than his gardener raised in the garden, but likewise larger and fairer. The soil of the experiment-ground is a rich black mold, worth twenty-five shillings per acre." It is commonly supposed, that plants of various kinds extend their roots as far under ground

ground as their tops spread above ground; and in several trials that have been made to discover the length of roots, they have been found to spread a great deal farther than was expected, though they are too small and tender towards their extremities, to be taken up without breaking them. Roots of wheat have been taken up that were extended three feet from the stalks. Whereas in the horse-hoeing they have only two feet five inches to spread from the rows to the middle of the intervals; and in the twelve-inch rows they have but six inches to spread, till they meet the roots of the adjoining rows. Why therefore should it be thought contrary to the nature of things, that wheat may not by culture extend their roots as far as such small low plants as lettuce and onions? I shall give some examples in extensive practice, and many more might be added, to shew, that wheat drilled with wide spaces, produce very profitable crops, and at a less expence for hand-hoeing than the above author has stated.

It cannot, however, be truly asserted, as by some has been done, that the horse-hoed crops of wheat are in general greater, or even so great as the sown crops, upon the same land, or upon land of equal goodness, and in the same years. The profit of this husbandry does not altogether consist in the superiority of the crops of this above the common husbandry; but principally in reducing the expence of cultivation, and saving that of manure; whereof none, or very little is necessary in the horse-hoeing husbandry for corn. This is an important article, and a necessary and very expensive one in the common husbandry. It is no small advantage in the hoeing husbandry, that all the manure usually bestowed upon the wheat crop, may be saved for the other lands; for the improvement of meadows and grass-grounds, and for the crops cultivated for cattle, turneps, carrots, cabbages, and cole-seed, and for domestic use, or sale, as potatoes, hops, madder, and several others.

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With regard to the crops obtained from land drilled in equidistant rows, and hand-hoed, though this method of culture is much inferior to horse-hoeing, as it does not near so much improve the land, nor so that successive wheat crops can be obtained from it; yet it is commonly more profitable than sowing it with wheat broadcast, and the land is, by the hand-hoeing, in much better order for a succeeding crop. Neither is the expence of hand-hoeing so great as the above author seems to think; for once hoeing is frequently sufficient, and it is very rarely necessary to hoe oftener than twice. The hoeing, sun, and free air between the rows, very much strengthen the plants, cause them to throw out many branches, and fill the grain. It is unnecessary to multiply examples of this, and may be sufficient to produce one that is unexceptionable, the experiment made by Mr. Cox, near Lymington, in Hampshire, being a comparative one between wheat
sown

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sown broadcast, and drilled in equidistant rows twelve inches distant; for which the gold medal was adjudged to him by the London Society of Arts, and is related by him as follows:

“Experiments in the culture of wheat, drilled in equally distant rows with a drill-plough, and sown broad-cast, in November 1767, by Mr. Mathew Cox, of Wallhampton, near Lymington, presented to the Society of Arts, &c. London.

“The Expence of Tillage, &c. per acre.

One Acre broadcast.

First ploughing,	—	—	0	7	0
Second ditto,	—	—	0	6	0
Third ditto,	—	—	0	5	0
Harrow,	—	—	0	1	0
Drag,	—	—	0	1	0
			1	0	0
Two bushels of seed,			0	15	0
			£.	1	15 0

One Acre drilled.

Three ploughings and harrowing,			1	0	0
Drilling, one man and boy, at one shilling and four-pence per day,			0	0	4
Hand-hoeing,	—	—	0	1	4
			1	1	8
One bushel of seed,	—		0	7	6
			£.	1	9 2

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No. of the expe- riments	When drilled	EXPERIMENTS on Wheat drilled in equidistant rows, 12 inches asunder.	Acres of land	Bushels of seed	Sheaves produced
No. 2	Nov. 6	White wheat on narrow lands, soaked in fresh water 12 hours, in brine 24 hours, and limed; hoed by children the 2d of May, at $\frac{1}{2}$ d. per row, which came to 1s. 4d. was out of the ground two days before the broadcast No. 1.	1	$1\frac{1}{2}$	151
4	Nov. 6 & 7	White wheat, on narrow lands, prepared as No. 1, &c. hoed by children, 4th of May, $\frac{1}{2}$ d. per row, which cost 1s. per acre. Most of the ears of this wheat and No. 2, were at harvest, 6 and 7 inches long. This piece, and No. 1, 2 and 3, were chalked, about 15 loads per acre,	2	$1\frac{1}{4}$	396
8	Nov. 7	White wheat, on broad lands, brined 12 hours and limed; hoed by my servant, 20th of May,	$1\frac{1}{2}$	$1\frac{1}{2}$	370
10 13	Nov. 7 March 11	White wheat on broad lands, had no manure, and limed only, Red wheat, on broad lands, $1\frac{1}{4}$ acre, $1\frac{1}{2}$ bushel of smutty seed, brined 48 hours and limed. The weather so wet, the seed could not be covered sufficiently. This wheat was mowed and given to the hogs. This land had borne a crop of carrots, which could not be cleared off, nor the ground prepared till February,	$1\frac{1}{2}$	$1\frac{1}{2}$	150

15 Nov. 20 Red smutty wheat, brined 5 hours and limed; hoed by my
 servant the 26th of May. }
 This had borne vetches in 1766, and had no manure,
 Total of the drilled crops

$\frac{3}{4}$	$\frac{3}{4}$	156
$6\frac{3}{4}$	6	1223

“ I had as much or more wheat from one bushel of seed sown in the drill way, as from two bushel sown in the common way. One bushel of lime, which cost seven pence, is sufficient for twenty bushels of seed. Chalk, &c. nothing charged to either, since the expence was the same, for the drilled and broadcast.

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“ The drilled wheat produced in general, six, seven, eight, and some twenty-five stems from one grain. No. 2 was remarkable for the number of stems from each grain, but the quantity of seed was too small. I look upon one bushel of seed to be quite sufficient for one acre drilled, The quantity sown commonly, in this county, is from two to $2\frac{1}{2}$ bushels per acre. At the rate which wheat is now sold, there is a saving in the drill method of sowing, of near the rent of the land; viz. twelve shillings and six pence per acre.

No. of the experiments.	When drilled	EXPERIMENTS on Wheat sown broadcast.	Acres of land	Bufshels of seed	Sheaves produced
No. 1	Nov. 5	White wheat, on narrow lands, soaked in fresh water 12 hours, in brine 24 hours and limed. Chalked with about 15 loads per acre. Sowed 2 bufshels of seed per acre. The lands, No 1 to 12, had all three ploughings, and were dragged.	1 $\frac{1}{4}$	2 $\frac{1}{2}$	190
3	5	White wheat, on narrow lands, prepared as No. 1 and 2, and chalked, at 15 loads per acre,	2	3	140
5	23	White wheat, on narrow lands, dunged and chalked, about 15 loads per acre. The seed brined three hours, and limed: 12 bufshels of foot sown on this piece, the 20th of January,	3 $\frac{1}{4}$	2	60
6		Red wheat, on broad lands, chalked and dunged as No. 5, and 18 bufshels of foot per acre, in January; the seed brined 3 hours, and limed, 2 $\frac{1}{2}$ bufshels of seed per acre. Small ears, but very good wheat,	3	7 $\frac{1}{2}$	490
7	15	White wheat on broad lands, footed as No. 6. Seed brined 12 hours, and limed,	1 $\frac{1}{2}$	2 $\frac{1}{2}$	380
9	7	White wheat on broad lands, dressed with foot as No. 6, the seed limed only,	1 $\frac{1}{2}$	2	240

11	7 White wheat, only chalked, brined 12 hours, not limed,	$0\frac{1}{2}$	2	150
12	7 White wheat, had carrots last crop, cleared off at Michaelmas, had no manure, the seed brined 12 hours and limed,	$\frac{1}{2}$	$\frac{1}{8}$	70
14	20 Red smutty wheat; not manured; seed brined a few minutes and limed; bore vetches in 1766,	$1\frac{1}{4}$	$2\frac{1}{2}$	324
16	23 Red smutty wheat, vetches in 1766; had no manure. Seed not brined nor limed. The ears very small, but the grains large. Near the hedge they were smutty, but not half so much as the feed,	$1\frac{1}{2}$	3	261
Total of crops broadcast,				14 $27\frac{3}{8}$ 2305

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" The field in which these experiments were made, is called Wimble Field, situated on Wallhampton-Hill, on the east side of Lymington river. It contains twenty-three acres within the fence. It is a shallow mould on a gravel. The whole field is nearly alike, excepting that from No. 12 to 16 the soil is a little lighter and deeper.

“ The number of sheaves produced by the drill culture were not so many in some of the experiments as by the broadcast, but they all weighed more, and produced more grain. The ears also were considerably longer; which I attribute to the hoeing, and the length of time the seed was steeped in brine. November 12, 1767.

“ November 19, N. B. Since I wrote the above, I have threshed a quantity of both the red and white wheat, and find, that twelve sheaves of the red wheat, cultivated in broadcast, yield one bushel of grain; whereas from ten sheaves of the white wheat, cultivated in drills and broadcast, the same quantity may be obtained. I have threshed five-hundred sheaves of the produce of each of the methods of culture; the sheaves were as equal in size as possible, and weighed about twenty pounds each. The ears I have sent to the society were not picked, but the general size of each experiment.”

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LETTERS to Dr. TEMPLEMAN, Secretary to the Society.

"S I R, Wallhampton, May, 2, 1768,

IN answer to yours, the seed was harrowed in, except the lands sown with the drill-plough, which were harrowed before they were sown. We sowed about three acres per day with the drill-plough, which finished. I think three bushels of lime were all that were used for the seed of this field. The first ploughing we charge six shillings per acre; the second five shillings, and the third four shillings. I have sown some wheat with the drill-plough last Michaelmas, have now sixteen stems from many of the single grains, and think it has not done tillering.

"S I R, Wallhampton, May 14, 1768.

I received your favour this morning. The land for the drilled wheat was pre-

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pared exactly the same as the land sown in the common way; only the land for the drilled-wheat was harrowed before the drilled-plough went on. My drill-plough sows four rows, and harrows it. I had on an average twenty-three Winchester bushels per acre drilled."

REMARKS ON these EXPERIMENTS.

The $6\frac{3}{4}$ acres drilled produced 1223 sheaves, whereof 1167 were from the 6 acres of white wheat, 10 sheaves of which yielded a bushel of grain, in all $116\frac{1}{2}$ bushels, and near $19\frac{1}{2}$ bushels per acre.

And the $\frac{1}{4}$ acre of red wheat produced 156 sheaves, at a bushel per 12 sheaves, is $20\frac{1}{2}$ bushels per acre. The average, therefore, of the drilled crop is nearly 20 bushels per acre, by computation from the sheaves; but Mr. Cox says he found the real produce, on an average, was 23 bushels per acre.

The

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The 14 acres broadcast produced 2305 sheaves, of which the $8\frac{1}{4}$ acres of white wheat yielded 1230 sheaves, at 10 sheaves per bushel, is $122\frac{1}{4}$ bushels, and $14\frac{1}{4}$ bushels per acre.

And the $5\frac{1}{4}$ acres of red wheat produced 1075 sheaves, at 12 sheaves per bushel, is $89\frac{1}{2}$ bushels, and $15\frac{1}{2}$ bushels per acre, consequently the average of the broadcast is 15 bushels per acre, computed from the sheaves.

But as the real produce of the drilled exceeded the computed, probably the difference in the broadcast might be nearly in the same proportion, viz. as 23 to 20; and in that case the real produce of the broadcast was $17\frac{1}{4}$ bushels per acre; which is $5\frac{1}{4}$ bushels per acre more from the drilled than the broadcast, at 7 shillings and 6 pence per bushel is, £. 2 3 $1\frac{1}{2}$

Alf.

	Brought over	2	3	1 $\frac{1}{2}$
Also a bushel in seed saved per acre,		0	7	6
		2	10	7 $\frac{1}{2}$
But in tillage, the drill cost more than the broadcast per acre,	}	0	1	8
The drilled most profitable per acre,		2	8	11

The rent is twelve shillings and six pence per acre; so that the profit of the drilled was more than the broadcast, very near four rents of the land: an ample encouragement to farmers to cultivate their wheat in this manner.

The hoeing being performed by children, it was probably done but superficially; and was only but once hoed. Had the land been well and deep hoed early in the season, and the hoeing repeated, the drilled crop would have been still more plentiful, and the land much improved for the succeeding crop. To shew this more plainly, it may be sufficient to refer to Mr. Tull's own experience, who first introduced into the fields the hand-hoeing

hoing of wheat and other crops. The account he gives of his hand-hoed wheat, is as follows, p. 50.

“ About the year 1701, says he, when I had contrived my drill for planting saint-foin, I made use of it also for wheat, drilling many rows at once, which made the work much more compendious, and performed it much better than hands could do; making the channels of a foot distance. Drilling in the seed, and covering it, did not in all amount to more than six pence per acre expence, which was above ten times overpaid by the seed that was saved: for one bushel to an acre was the quantity drilled. There remained then no need of hand work, but for the hoeing; and this did cost from half a crown to four shillings per acre. This way turned to a very good account, and in considerable quantities. It has brought as good a crop of wheat on barley stubble, as that sown the common way on summer fallow; and when that sown the old way,
on

on the same field on barley stubble, entirely failed, though there was no other difference but the drilling and hoeing. It was also such an improvement to the land, that when one part of a strong whitish ground, all of equal goodness, and equally fallowed and tilled, was dunged and sown in the common manner; and the other part was drilled and hand hoed without dung; the hoed part was not only the best crop, but the whole piece being fallowed the next year, and sown all alike by a tenant, the hoed part produced so much a better crop of wheat than the dunged part, that a stranger would have believed by looking on it, that, that part had been dunged which was not, and that part not to have been dunged which really was."

And in 1738 he writes as follows, "I was desired to take an exact account of the product of a single land of hand-hoed wheat, and of an acre in the middle of a field

field of twenty-five acres of horse-hoed wheat, in order to know the different quantities produced by them.

The acre of horse-hoed wheat yielded twenty-nine bushels and six gallons (nine gallons to the bushel) but there was very great waste made by the reapers to whose lot this acre fell. This waste was greater than any I had ever seen; so that I believe, if it had been as well reaped as most of the rest of my wheat was, there would have been thirty-two bushels received from this acre.

The land of hand-hoed wheat was in a common field, and planted upon the level, with the famed drill that planted the other, whereby there was a space of ten inches between two rows, and a space of eighteen inches between those and the next row; so that each row had fourteen inches of surface for the roots to spread in. It was hand-hoed very well. The land hath not been dunged in any manner since the year 1719. This crop

was

was reaped very low, and thrashed out immediately. It produced eleven bushels and a half; the measure of the land being fifty-two perches, the product is at the rate of thirty-six bushels and six gallons to an acre. It is situated next to the ditch of a meadow, and is all the land I have in the common field. The lands adjoining to it, of the same goodness, were judged by all gentlemen and farmers who viewed them, not to have above half the wheat on them that this had, perch for perch; and yet there was no difference in the management, except this being regularly planted and hand-hoed, without dung; and the other sown at random, and dunged (as they always are, once in three years) the fallowing and ploughing of both were the same. Mine was said by several farmers of the place, to be the best land of wheat in the parish.

“This indeed ought to be allowed, that mine being mostly white cone

wheat, and the adjoining lands of clean lammas, might make some part of the difference : but there being some of the same sort of lammas amongst this cone, it was observed to be as high as the cone, and the ears of it to be of double the goodness of those in the contiguous sown lands.

“ The difference of the appearance of the hand-hoed and of the horse-hoed, whilst they were standing, was so great as to deceive many who saw them, and to induce some to imagine, that the product of the former would be double to that of the latter; though it was really little more than an eighth part greater.

“ The horse-hoed shews the whole interval empty, until the grain is almost full, which is a great advantage to the crop: because unless the air did freely enter therein, to strengthen the lower parts of the stalks, they would not be able to support such prodigious ears (some
con-

containing one hundred and twelve large grains apiece) from falling on the ground."

And p. 274, he says, "My single land of fifty-two perches in the common field, mentioned in my *Addenda*, brought the last harvest a crop of barley (in the opinion of all who viewed it) double to the land of the same goodness contiguous to it, at the end and side of it. This shews that the benefit of the pulveration of one good hand-hoeing, performed half a year after planting the wheat, together with the less exhaustion of half the seed, and no weeds, vastly exceeded the use of the dunging for the wheat, on the contiguous land, there being no other difference."

These examples sufficiently prove the advantage of drilling wheat in rows, twelve inches and more distant, for hand-hoeing; and that it is a much more profitable method than sowing broad-cast. The objection to the wide spaces between the rows is of no weight. The plants

plants receive their nourishment by their roots; the more numerous they are, and the more competent room they have to spread, the greater share of nourishment the plants receive from them. In one case the hand-hoeing opens the soil so much, that they extend through the twelve and fourteen inch spaces; but in the other the soil is so much more opened by horse-hoeing, that two rows only, upon a ridge fifty-seven inches broad, produced near four quarters of wheat per acre, nine gallon measure. As the partition between the double row on the top of the ridge, was only ten inches wide, the interval between the double rows, was forty-seven inches, or near four feet wide, through which, notwithstanding, the wheat roots extended, as appears by the goodness of the crop. The distance, therefore, between the rows of twelve or fourteen inches is no valid objection to this manner of drilling wheat to be hand-hoed.

On the contrary it has been found, that drilling the rows two feet distant, produces better crops than at half that distance; provided the mould between such wide rows is well hoed; for which purpose a small plough is much preferable to the hand-hoe, and the tillage cheaper.

In close drilling, the rows are planted about seven or eight inches asunder. The crop is not so good as the twelve inch rows; but is equal to, and often better than the broad-cast, and half the seed is saved; for in close drilling about one bushel of seed is sufficient. Many farmers approve of this way more than the twelve inch rows; because the ground is more covered with plants, and that it is not necessary to hoe them. Where a considerable extent of land is drilled in this manner, the saving of seed is an object deserving the farmers notice. The following instance from Mr. Craik, near Dumfries, in Scotland, is sufficient to shew

shew this: writing of his drill-plough he says, "Those who do not incline to dip into the horse-hoeing husbandry, may use this drill to sow their fields in close drills, which will be a saving of more than one half the seed. I was lately with a gentleman in Annandale, who told me he sold for fifteen pound this spring, the oats he sowed in seed, by sowing his fields with my drill-plough, and yet I have not seen a finer crop this season, though neither horse or hand-hoed."

I have taken notice above, that the last mentioned author has objected to the drilling or horse-hoeing of wheat, on account of the wide spaces between the rows—That Mr. Tull laid his land into six feet ridges, and drilled two rows upon each ridge; and therefore that only four inches in seventy-two was planted, the remaining sixty-eight inches having no crop upon it, but was left unplanted, in order to introduce the hoe-plough—That he directs six, or even eight hoe-

ings to be given to a crop—And that, at the summer hoeings, the plough should not come very near to the rows of wheat.

“The third hoeing (in summer) says he, p. 182, was performed in a particular manner, as well as the first and second: for as the fibres of the roots had now acquired considerable strength, and were known to have extended a considerable way into the intervals, Mr. Tull judged it improper to tear any considerable number of them off at once with the plough, and therefore his instructions to his ploughmen were, to keep at a greater distance from the rows, and to depress his left hand, that by the slant position of the plough, the share might pass over the lowermost extended fibres without hurting them, and at the same time by loosening the earth above and beyond them, lessen the impediment that might have retarded their farther extension.”

“After this hoeing the plants were suffered to remain a shorter or longer time,

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time, according to the appearance of the crop, or the increase of the weeds. If the plants appeared sickly, they were immediately restored to health by the application of the hoe; or, if the weeds had gained ground, they were removed by the same means.

“The last hoeing, however, which was sometimes the sixth, or even the eighth, was always performed as soon after the wheat was out of blossom, as the weather would permit. This hoeing Mr. Tull esteemed one of the most essential.

“Those who would be satisfied of every little nicety, must consult Mr. Tull’s book of horse-hoeing husbandry, which in truth deserves to be more generally read, than, I believe, it has hitherto been.”

Here it is to be observed, that the horse-hoeing was a new method of husbandry, never practised in the culture of wheat, till it was introduced by Mr. Tull: and it may be supposed, which indeed is

the fact, that his first essays were imperfect, or capable of improvement; and accordingly we find, that upon further experience, he made several important alterations and improvements upon his first practice. How it has happened, that this gentleman, who describes this husbandry, should take notice of Mr. Tull's first practice only, and wholly omit these improvements, must be attributed to his not having read the latter parts of Mr. Tull's work: for his book of horse-hoeing husbandry, properly so called, contains his first practice; but he published several additional parts at different times, during a course of six years; which it is necessary for those who would make trial of this husbandry, and perform it in the best manner, to be acquainted with.

That he altered the breadth of his ridges, from six feet to four feet eight or nine inches, appears from the following passage in his *addenda* to the book of horse-hoeing; where he says he made
fourteen

fourteen ridges in the breadth of an acre, or four perches. P. 262.

“ I now chuse, says he, to have fourteen ridges on an acre, and one only partition of ten inches on each of them. This I find answers all the ends I propose. If the partitions are narrow, there is not sufficient room for the hand-hoe to do its work effectually ; if wider, too much earth will lose the benefit of the horse-hoe.—By all these three methods, (viz. double rows planted upon level ground ; treble rows upon six feet ridges ; and double rows upon narrow ridges, of fourteen ridges on the breadth of an acre) I have had very good crops ; but this I now describe is the latest, and, as it ought to be, the best ; I publish it as such, without partiality to my own (former) opinions.”

And, with regard to the manner and number of the horse-hoeings, he directs in his *Conclusion*, or last part of his work, as the result of all his experience, p. 272.

“ At the second (or spring) hoeing, says he,

he, the plough goes in the furrow of the first; making it deeper and nearer to the wheat. The third hoeing fills up this furrow; and then at the fourth hoeing, the plough goes in the same place as the second, turning the mould into the interval. It is remarkable, that though the furrows of the second and fourth hoeings be deep and near to the rows, seeming to deprive the wheat of the mould which should nourish it, whereby one would imagine, that these furrows lying long open should weaken or starve it, but it is just the contrary; for it grows the more vigorous. And it is the observation of my ploughmen, that they cannot at those hoeings go too near to the rows, unless the plough should tear out the plants.

“If I may presume to assign the cause of this surprising effect, it is, in my opinion, the following, viz. This open furrow has a double surface of earth, which by the nitre of the contiguous atmosphere,

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sphere, is pulverised to a great degree of minuteness near the row. The roots that the plough cuts off on the perpendicular side of the furrow, send out new fibres to receive the pabulum from this new made pasture: and also part of this superfine powder is continually falling down into the bottom of the furrow, and there gives a very quick growth to those roots that are next it, and a quick passage through it into the earth of the interval, where they take likewise the benefit of the other side of this pulverized furrow. When it is said that air kills roots, it must not be understood that it kills a plant, unless all, or almost all its root is exposed to it, as it is not in this case. Some think that there are roots that run horizontally, below the plough into the interval: but of this I am not convinced.

“ It is not often that we hoe above four times; and then the furrow is turned towards the row at the third time only.

“ There

“ There being no danger from these furrows lying long open, we are not confined to any precise distance between the times of hoeing ; for which we need only regard the weather, the weeds, and our own convenience of opportunity and leisure.—Whether these furrows lying long open next the rows in very hot dry climates may be prejudicial, cannot be known but by trials.—I prefer planting the rows on the precedent intervals.

“ The number of ridges being encreased, as their breadth is diminished, occasions somewhat the more plough work ; we likewise use more handwork than formerly : but the profit of this encreased labour, is more than double to the expence of it.

“ It is better to make fifteen ridges on an acre, than to leave any earth unmoved by the hoe-plough in the middle of the intervals. But when ploughmen by practice understand well to use the hoe-plough, they will plough the intervals
clean,

clean, though the ridges are only fourteen on an acre."

It is evident from these passages, that Mr. Tull's improved method, was to drill his wheat, not upon six feet ridges, but upon narrower ones of four feet eight or nine inches.—That he commonly hoed his wheat only four times. And that he horse-hoed it close to the rows every time in summer. Also that is not necessary to be critically exact, with respect to the times of hoeing. And upon the whole it appears that horse-hoeing of wheat, is not so nice and difficult as many seem to apprehend. The most extraordinary circumstance is, that the wheat continues to thrive after the earth is ploughed away from the rows towards harvest, when the plants are at their full growth, and the grain filling; which I am certain is a fact, from inspection of several crops so done; though I have not myself practised that method; because it requires more time and ploughing to form the

new

new ridges for the next crop, than is necessary, when all the earth is ploughed up to the rows at the last hoeing; provided the next crop is to be drilled upon the former intervals, which is the most expeditious, and, in my opinion, is in general the best way.

And that the reader, who would practise this husbandry, may be further satisfied, that the method here directed by Mr. Tull, has succeeded with others since, I shall give another nearly similar to it, practised by Mr. Craik, as described by himself; after reciting what he says of the nature of his land.

“ My soil, says this gentleman, is stiff and very moist; that is, the bottom below the staple is a hard and almost impenetrable till, impervious to water, which of consequence keeps the top poachy: and therefore am obliged to drain every field with covered drains, filled with stone. Add to this, that our climate is extremely watery: so that both soil and climate are

against me, especially in the new husbandry.

“ About seven years ago, I began to drill wheat in double rows, on ridges five feet two inches broad, but have now reduced them to four feet ten inches, on the last taken in fields, which size I find answers every purpose best for double rows. I drill a little short of a Winchester bushel to the Scots statute acre (viz. one acre and a quarter English); my return, upon the average, is about twenty-five of said bushels, since I first began: and the total expence, harvest-home, is about a guinea, seed included. But the return would considerably exceed this, were it not for some parts in every field, that have every year quite failed; in some occasioned by a vein of sandy gravelly soil, that runs across two of my fields; and in all the others, from the old ridges being very high raised by the former farmers, and at the same time very broad and crooked; which obliged me to level the whole;

whole : the consequence of which is, that the tops of the old ridges continue barren for several years, to my great loss. I was for some time in hopes that frequent cultivation and exposure to the air, would in time remedy this defect, but finding little alteration in those parts, I am now applying proper dressings, suited to the different soils, which I have already found will answer the purpose, and make a very sensible difference in my profits.

“ When the crop is off, the ridges are ploughed up and formed anew ; then smoothed by the drill harrows, and drilled with the drill-plough, which delivers the quantity of seed intended, and exactly at any proposed depth, covers and rolls it at the same time, and is so simple, that any person may conduct it at first trial. When the wheat has got three or four leaves, I hoe from the rows, agreeable to Tull. In the spring, I always deepen the same furrows made before winter ; after which it lies till the wheat begins to spindle,
when

when I horse-hoe back the earth, so as to earth up the plants two or three inches, to strengthen and secure them. In this operation, a slip of earth remains untouched, in the middle of what was ploughed first from the rows; and as a new surface is exposed by the last hoeing, I leave that slip untouched for some time, to receive the advantage of exposure, and till the weeds come, when I plough up this slip with the double mould-board plough, which covers the weeds and leaves a wide, deep, and clean trench. If the wheat stands fair, so as to admit the horse-hoe, which with me is seldom the case, I hoe a small furrow back from the rows, and return it with the double mould-board plough; but do not think this necessary, if the former operations are properly executed.

“ Though my soil is stiff and heavy, I only use two horses to the single hoe, and three to the double mould-board hoe. The single hoe hoes two and an half Scots

acres per day, and the double mould-board five: the first having a full bout to each ridge, the other only a half bout. I have tried to hoe with oxen, but found they did not answer in my wet soil, and now only use horses, as they poach the land less.

“I have now the seventh crop of drilled wheat, growing on my first acre, which I chose as near the average of my soil as I could, and it at present promises to be the best. This acre consists of twenty-two ridges, nine of which were three years ago strongly dressed with dung, that side being lighter land than the other, and generally failed. Since dressing, that part has proved better, but still inferior to the undunged side. This acre, as well as all my fields, was dressed at first with shells, and bore four broadcast crops immediately preceding the drilled crops. I have only this year thirty Scots acres of drilled wheat; the wet seed-time last year having prevented my drilling a ten acre field,

field, now in turneps and potatoes: for I dare not touch my soil with the plough when wet.

“ The field with the sixth crop of drilled wheat, and which had five broadcast crops previous to these, hath at present as full a crop as can stand upon it, except where the sandy vein comes in. The field, with the fifth crop, is inferior to it, though equally good soil. In general, where the soil was originally tolerable, and, exclusive of the particular accidents I have mentioned, I cannot perceive hitherto any decline in the crops, even those that have not received any dressing with dung; but how long this will go on, time only can determine.

“ I have used the white lammas wheat, the Kentish red, the Zealand from Holland, the white and gray cone, and this year a small quantity of Smyrna wheat, *spica multiplici*; yet I find none of them can resist the violent storms of wind and rain of our climate. Both the cones

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stand

stand the best; but our millers have not art enough to grind them; on which account our bakers are shy to buy them. I have mostly sown the gray cone. A great part of my last year's crop went to the Isle of Man, to Ramsey, and was so large a grain, that our bakers objected to it on that account.

“My crop this year consists of the gray cone, the red Kentish, and the white lammas, some of each in the same field, on purpose to see which stood best; and now find the red Kentish has suffered most, and the white lammas, of a kind I had from London, stands equally well with the gray cone, which has determined me to sow it mostly, for the ensuing crop.

“This year's crop had more than usual a luxuriant appearance, both the drilled and broadcast; but when it came to be cut down, I found it almost quite ruined by the blight, occasioned, I suppose, by the uncommonly cold and wet months of May and June, together with the cold
and

and moist quality of my soil. The broadcast appears rather to have suffered more than the horse hoed, though all of the gray cone, are a hardy sort. I am afraid this will be but too general, as I am informed by some of my correspondents of the London Society, that they have observed, that even the grasses have not perfected their seeds this season.

“ My drilled wheat is generally, by the time it gets into blossom, so laid over, but not broken, that I can neither horse-hoe, hand-hoe, or hand-weed; so that a second crop of weeds never fail to spring up, time enough to ripen the seed, before the crop is cut; and this, with me, is the great and invincible objection to a succession of wheat crops in this way; at least in my soil, and this climate. What I propose to remedy this is, to take a crop of horse-hoed turneps, next a horse-hoed crop of beans, and next two or three crops of horse-hoed wheat, and then return to the turneps. In this way I am sure to

extripate the weeds during the turnep and bean crops ; and have reason to expect my wheat should be a full crop, after these meliorating ones.

“ Were it not for the parts that fail in my fields, my horse-hoed crops would exceed four quarters. Last year on half an acre Scots, I had twenty-two Winchestersters ; but this was all equally good.

“ I always horse-hoe from the rows at one bout, half a bout to each side, and could return this bout with the double mould-board, at half a bout ; which was for some time my practice ; but now find it more profitable, first to return the bout by another bout of the single hoe ; which exposes a large new surface : and then, when the weeds are up, clean up with the double mould-board. But as, at the second hoeing from the rows, which is after the grain has got into ear, I only take two small furrows, viz. one from each side, these I return at once, with the double mould-board.”

This

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This gentleman's account of the horse-hoeing of wheat, is very clear and concise, and merits the particular attention of those who are inclined to practice this husbandry; the success whereof is very apparent here, notwithstanding the very unfavourable soil and climate.

“ The objection made by the forementioned author, to the wide spaces between the rows, and supposing them to be so much waste ground, is here demonstrated to be groundless. Mr. Craik's ridges are four feet ten inches broad, and the partition between the double row on the top of the ridge eleven inches: the horse-hoed interval, therefore, is near four feet broad, which, though no plants grow upon them, yet furnish the roots of the double row with so much nourishment, that the crop is as good as the broadcast, that covers all the ground with plants.

Likewise, instead of six or eight hoeings, as mentioned by the said author, Mr.

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Craik gives only four hoeings, the effect whereof is very great.

The profit likewise from this culture is remarkable. The total expence of cultivation, harvest-home, and seed included, being about a guinea per acre, if the expence and rent amounts to forty shillings per acre, the crop of four quarters per acre, which he says they exceed, exclusive of the tops of the old ridges, and sandy vein, being reckoned only at eight pounds, there remains six pounds per acre. A profit greatly exceeding that of common wheat crops.

Sir Digby Legard says, the farmers profit on the Yorkshire wolds, from their wheat and barley crops, is only about four shillings per acre. And the Complete English Farmer reckons that the occupier of a farm of two hundred pounds a year rent, consisting of five hundred acres, viz. about three hundred acres arable, and the rest meadow, pasture, &c. ought to have a capital of fifteen hundred pounds.

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“The whole sum which such a beginner, says he, p. 62, should be possessed of, should not be less than fifteen hundred pounds; for neither will the farm be over-stocked, nor the stock over-rated.— He must not flatter himself, that less than fifteen hundred will suffice. Let him remember, that if he once gets the name of a bad paymaster among his neighbours, it will require many years close application to business to redeem his credit; and that up-hill work, as the phrase is, long continued, will tire the best horse in the farmer’s team.”

The profit arising from this farm, so stocked, he estimates at about fifty pounds a year, being, he says, what the farmer can expect to save at the year’s end, over and above maintaining his own private family. “Fifty pounds a year, says he, p. 204, laid by in clear profit, is nearly as much as a farmer can annually accomplish, who rents two hundred a year.”

The sum he supposes necessary to begin with, is much beyond what farmers in general can attain to, who rent farms of two hundred a year. And if so much was necessary, and the profit so small, few persons, I believe, could be found capable of renting them; and very few would breed up their sons to agriculture.

Hence, however, the advantage of horse-hoeing culture is very apparent: for, according to Mr. Craik's practice, twenty-five or thirty acres of horse-hoed wheat would be as profitable as five hundred acres, according to the above estimation. It is true he finds it very difficult to keep down the weeds, that are apt to rise and multiply the latter end of summer; and his intermediate crops of turneps and beans are not so profitable as the wheat: but with regard to soil and climate, his situation is peculiarly unfavourable; and his success, notwithstanding these circumstances, is an argument rather in favour of
of

of the hoeing husbandry for wheat, as it undoubtedly is of his skill and good management.

The expence of a guinea per acre, may be thought low, by those who have not experience of the horse-hoeing husbandry, yet sir Digby Legard's expence was much lower: for in his light land he found one horse sufficient for hoeing. And Mr. Wynn Baker, experimenter in agriculture to the Dublin society, and who keeps an exact account of the expence of his horse-hoeing culture, for the inspection of the society, found that it amounted only to twenty-three shillings and three pence halfpenny per Irish acre, seed included, and an Irish acre is about an acre and a half English, the proportion being nearly as five to eight.

The particulars of this expence, he states as follows; per acre (Irish)

	£.	s.	d.
Ploughing the land once, which is sufficient after the first year,	-	0	15 4
Drill-harrowing, 4, 5 or 6, acres a day, with one horse,	-	0	0 6½
Carried over,	0	10	10½

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	£.	s.	d.
Brought over	0	10	10½
Drilling, from 3 to 5 acres a day, with 2 horses, holder and driver,	0	1	1
Seed, generally 5 stone or 9 gallons, but he charges 6 stone, or near 11 gal- lons,	0	6	0
Winter-hoeing, with 2 horses. He never hoes less than 2 acres a day,	0	1	7
Spring-hoeing with M. de Chateaux's miner, with one horse,	0	1	1
Summer-hoeing with 2 horses,	0	1	7
Last hoeing with miner, and 1 horse,	0	1	1
—Weeding and reaping uncertain, not charged,	1	3	3½
Rent,	0	18	0

£. 2 1 3½

Mr. Baker compares the expence and produce of horse-hoed wheat, with that of the common husbandry in Ireland, where he observes their usual method is to fallow the first year, the second to sow wheat, and the third year oats, which finishes the course, and then return to fallowing: so that they have only two crops in three years. The particulars as follows, viz,

	£.	s.	d.
First ploughing for fallow, 8 horses, 8s. two ploughmen, 1s. 4d. two drivers 1s.	0	10	4
First hoeing, 4 horses 4s. driver 6d.	0	4	6
Second ploughing and harrowing,	0	14	10
Third ploughing, called stretching,	0	10	4

Carried over 2 0 0

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	£.	s.	d.
Brought over	2	0	0
Sowing the seed. Seedsman,	0	8	
Eight horses,	8	0	
Two ploughmen,	1	4	
Two drivers,	1	0	
	—	0	11 0
Seed wheat one barrel, or 20 stone, viz. } 36 gallons,		1	0 0
Rent for the year of fallow,		0	18 0
Ditto for the year of the wheat crop,		0	18 0
		—	—
		5	7 0
The expence of the oat crop,		2	5 0
		—	—
The produce of the acre of wheat, he esti- } mates 9 barrels, at 20s.		9	0 0
And of the acre of oats, 14 barrels, at 6s.		4	4 0
		—	—
He computes the drilled-wheat crops at 6 } barrels per acre,		6	0 0
		—	—
The expence whereof as stated as above.			
That in 5 courses, or fifteen years, the pro- fit in the common husbandry amounts to	27	19	2
And the profit of the drilled in that time to	52	3	11
The superior profit of the drilled being therefore 24l. 4s. 9d. is 1l. 12s. 3½d. per acre per annum more than the common husbandry.			

“ The opposers of the drill husbandry, says he, have generally urged, that it is more expensive than the common husbandry, and that therefore it required a greater capital to conduct it. The preceding accounts (upon the faithfulness of which

which my credit shall stand) shews the first assertion to be wrong, and consequently the conclusion cannot stand. At the same time I must add, that no man, upon his beginning this culture must expect, that he can conduct it upon such low-terms, as he will after having had a little practice; any more than he will know how to build upon the best terms, when he first engages in it.

“The advocates for the drill-husbandry, have generally stated the produce as being more than the common husbandry. Perhaps that very circumstance has been injurious to the system. For I am afraid, and indeed I do believe, that when the land shall be equally prepared, and the broadcast does not happen to lodge, which it is more liable to do than the drilled, that the common sowing will produce the most for one crop; but then the wheat crop consumes two years, whereas the drill culture produces a crop every year after the first.

“The

“The fact to be ascertained by the two acres of ground already spoken of, seems to be, which method will produce the most corn. But in my judgment, that is not the capital point. The fair question seems to be, which of these two acres will produce the most money, in any given number of years, upon a fair account of profit and loss; regard always being had to the point of giving the common husbandry two crops for every fallow. For the ascertaining this capital and main point, my intention is, to keep the drilled acre under wheat for six or nine years; and the other acre under the common course of tillage for the same time.

“For the present I shall conclude this subject, with only observing that wheat raised in the drill-husbandry, will always bring a better price, than that raised on the same land in the common husbandry; because it will produce more flour, and is much finer for seed-corn.—And that

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the land under the drill culture, is always in high condition to be laid down for grass, which that under the common husbandry is not."

Mr. Baker describes his land, as a grey, stiff, stubborn, and infertile soil, lying upon a bed of limestone, at a small depth below the surface. Yet we find, by his account, that two horses were sufficient for horse-hoeing it; except, as he mentions in another place, in very hot weather, and then he used three horses. His ridges are five feet broad, and he drills two rows of wheat upon each ridge. He gives but four horse-hoeings to a wheat crop, and two of them with the miner, which is only a small single hoe, that goes under the surface; but it does not turn a furrow, and neither changes nor enlarges the surface, which is a great disadvantage to the growing and succeeding crops; no other instrument being so proper for that purpose as the horse hoe, or swing-plough. And perhaps it was owing
to

to this, and the intractable quality of Mr. Baker's land, that the superiority of his hoeing culture over the common husbandry, was not greater than one pound twelve shillings and three pence three farthings per acre.

The saving of so much seed in the drill culture, is an object of very great importance: for half the common quantity is sufficient in drilling upon level ground, or broad ridges, to be hand-hoed. And nearly the same proportion is saved in close drilling. But for horse-hoeing, two thirds of what is sown broadcast may very well be saved.

Having shewn some of the advantages that may be expected from this method of culture, confirmed by the extensive practice of several persons, and on land of different qualities; I shall next lay before the reader, the principal objections made to it, particularly those made by the author of the Complete English Farmer; whose knowledge of agriculture is conspicuous;

spicuous; but who appears to be prejudiced against the new husbandry, in regard to the cultivation of wheat. I have already taken notice of his mistake relating to the wide space between the rows; and, as I proceed, shall make some observations upon his other objections.

“The reader, says this gentleman in his preface, must not expect, in a work like this, many new discoveries. It is no part of my design to amuse the world with novelties. I am rather inclined to the practice of the old husbandry, though I fully and frankly acquiesce in the principles of the new. My reason for this seeming contradiction is, because I am not without some suspicion, that the mighty things which have been said and written of the advantages accruing from the new, are deduced from experiments in *small*, or upon lands of a peculiar kind, and not from a general course of practice upon lands of all kinds, confirmed by the experience of any given number of years.”

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In answer to this objection I shall refer the reader to what is mentioned above, concerning Tull's own success, upon land differing in quality, but mostly light land; Sir Digby Legard's, all light land; Mr. Craik's and Mr. Baker's strong land; and Mr. Deane's, of Woolhampton, near Reading, very strong land, upon which he cultivated wheat in the way of horse-hoeing above twenty years, with success. Mr. Craik takes notice, that he began this husbandry in a field, where the quality of the soil was, as near as he could judge, the average of all the land he employed in this culture; and that the hoeing so much improved it, that his crops from it, after a six year's trial, continued to be superior to those on his other lands of the same quality, that were cultivated later in this manner. And Mr. Baker's experiments of the horse-hoeing and common husbandry were made in the same field, upon lands adjoining to each other, and of the same quality.

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“ But,

“ But, say the favourers of this husbandry, it is the uninterrupted succession of crops upon the same land that gives the advantage. If that, indeed, could be obtained, and the labour remitted, the fact must stand confessed. But five or six ploughings, or if you will, horse-hoeings, are necessary in order to the growth of the present, and as a preparation for every succeeding crop; and five or six ploughings cannot be performed without a very considerable expence.”

The author seems here to take it as a settled point, that five or six horse-hoeings are the same, in point of labour and expence, as so many common ploughings. But should he not have taken notice of what Mr. Tull has said upon this head, as he frequently refers to his book on other occasions?

“ In plain ploughing, says Mr. Tull, p. 123, six feet contain eight furrows; but we plough a six feet ridge at four furrows—Now what we call one hoeing,
is

is only *two furrows* of this ridge, which is equal to a fourth part of one plain ploughing; so that the hoeing of four acres requires an equal number of furrows with one acre ploughed plain, and equal time to do it in. Except that the land that is kept in hoeing, works much easier than that which is not.

“All the tillage we ever bestow upon a crop of wheat that follows a hoed crop, is equal to eight hoeings, two of which may require four oxen each, one of them three oxen, and the other five hoeings two oxen each. However, allow three oxen to each single hoeing, taking them all one with another, which is three oxen more than it comes to in the whole.

“The expence, then, of hoeing six acres in a day in this manner, may be accounted at one shilling the man that holds the plough, six pence the boy that drives the plough, one shilling for the six oxen, and six pence for keeping the tackle in repair. The whole sum for hoeing

these six acres is three shillings, being six pence per acre. But where there is not the convenience of keeping oxen, the hiring price of hoeing with horses, is one shilling each time."—So that the whole expence of tillage to an acre of wheat, viz. for one ploughing to form the new ridges, and six hoeings afterwards, if done by oxen, is four shillings, and by horses eight.—But here it is to be observed, that this tillage was given to six-foot ridges, with three rows of wheat upon each ridge. But when Mr. Tull altered his ridges to four feet eight or nine inches broad, and two rows upon each ridge, he found four hoeings were generally sufficient, as mentioned above. And when he discontinued the six-foot ridges, that three small oxen were enough for hoeing, at all times: for this he says in his addenda, p. 263.

"I now use no oxen, properly so called, but only bulls, bought in at the time when they are cheapest, and have them castrated.

castrated. These are hardier than oxen, though of a lesser size. Oxen being castrated while they are calves, grow much larger than bulls. We never put more than three of these (they are called bull-stags) to a hoe-plough."

Add to this what is said above of Mr. Craik's tillage, and Mr. Baker's, who used only two horses for hoeing, and hoed the crop only four times, and it will appear evidently, that the expences of ploughing the whole ground, and hoeing a fourth part of it are very different; and that four hoeings should not have been charged, as the same thing with six whole ploughings, as the above author has supposed in the place above quoted, and in some other parts of his work. I shall next proceed to what he says of weeding, in the preface.

"It is well known, says he, to those who are accustomed to the culture of land, that in the intervals of well cultivated ground, weeds spring up the readiest

and thrive the fastest, and that it requires more than ordinary pains to subdue them; that in certain rainy seasons this is impossible; and that in seasons when it is possible, other business will sometimes interfere, so as to make it very inconvenient to catch every opportunity that offers; and yet if an opportunity is suffered to escape, the lapse is irrecoverable. If such be the critical situation of hoeing, and such it most certainly is, in large concerns, can it be supposed that prudent men will risque the success of their crops upon such uncertainties?"

This, it must be acknowledged, is an objection of some weight; weeds being great enemies to farmers, in both the old and new husbandry. The author, indeed, seems to think, that in the new husbandry it is not possible to subdue them, and that if they are not subdued, they will destroy the crop. But we cannot in this case argue fairly from the old husbandry to the new; because the farmers in the old husbandry

bandry are often bringing a new stock of weeds to their lands, in the dung and other manures they lay upon them, and can never totally subdue the weeds, by sometimes a fallow, and the common change of crops.

But in this respect the horse-hoeing husbandry is very different; no dung, or other manure containing any seeds of weeds, are laid upon horse-hoed wheat; but on the contrary, the stock of weeds are diminished by hoeing and weeding; and by that means they will be subdued, with proper care, which is necessary in every method of husbandry. Mr. Craik's land is, indeed, an exception, as in some years he found it impracticable totally to subdue the weeds. But his situation is singular, and cannot be any just objection to the hoeing culture in general. Yet his course of two or three drilled wheat crops, beans, and turneps, is much more more profitable than the common course in the old husbandry. It is undoubtedly

necessary that those who would practise the new husbandry for wheat, should first make their land very clean by fallowing, or hoed crops of turneps or other large plants, and then it may be kept so; unless weeds can multiply by equivocal generation.

“Moreover, in stiff clays, neither the drill nor the horse-hoe can be introduced, generally speaking, to advantage. Land of this stubborn nature can seldom be brought to such a tilth as to admit of either; for land must be made very fine before the most perfect drill-plough that I have ever yet seen, can work with that degree of certainty as is necessary to plant equally the respective rows: and in summer, when the assistance of the horse-hoe is most wanted, such soils are apt, if the weather be dry, to be so hardened as not to be removed without annoyance to the rows; and if wet, clay is so tenacious of rain, and so poachy, that any attempts to loosen the soil in that situation, would serve only to compress it. The horse-hoeing

hoeing husbandry therefore can never be the general husbandry of England, where at least two parts in three of the arable lands are clay."

A considerable part of the arable lands in England is strong, but that they are clay, properly speaking, will not readily be admitted. It is likewise undoubtedly true, that strong stubborn soils are of difficult culture, in every mode of husbandry: but as appears above, not impracticable in the drill culture. For it is to be observed, that such strong lands and even clays are cultivated for wheat in the old husbandry, and with the same kind of instruments as are used in the new, to prepare them for drilling. Ploughs and harrows, and of late the spiky roller, are the instruments employed to reduce and prepare strong land, to be sown broadcast, and the very same are applicable to such land to prepare it for drilling: for when a drilled crop is carried off, the ridges upon which it stood, are to be ploughed
for

for another crop, as in common ploughing, with this advantage, that above three fourths of these ridges are well prepared for it, being broke and reduced by the several preceding horse-hoeings, and no long roots of couch, or other rank weeds in it, to bind the soil. And for the same reason, the middle of the ridges, upon which the two rows of wheat stood, being only about fourteen or sixteen inches in breadth, are more easily ploughed by two furrows, than can be done in common tillage; where the land is sometimes stale, and is generally bound and held together by the roots of weeds or clover. The fact therefore is, that these small ridges are more easily cultivated and prepared for a succeeding crop of wheat, than can be done by the old husbandry, in the same sort of land.

As to the objection that such soils are apt, if the weather be dry, to be so hardened as not to be removed by the hoe-plough, without annoyance to the

rows; those who have cultivated wheat with the horse-hoe in strong land, have not found this inconveniency, so as to prevent that operation. The hoer's attention is engaged to keep his land in good tilth; and in dry seasons and very stiff land, this is very difficult to be done with the plough or harrow. But Mr. Tull has recommended another instrument for breaking such dry hard soil, a stone roller, that is very effectual in the horse-hoed intervals, which are about four feet wide.

“ This stone cylinder, says he, p. 200, is two feet and a half diameter, and weighs eleven hundred weight besides the limbers, must never be used but in the driest weather, when neither the plough nor harrows can break the clods, and then being so very ponderous and short, only three feet long, it crushes them to powder; or into such very small pieces, that a very little rain, or even the dews, if plentiful, will dissolve them.

“ I have

“ I have had great benefit by this roller, in preparing my ridges for turneps. The weather proving dry at midsummer, which is the best season for planting them, the land was in pieces like horse-heads, so that there was no hopes of reducing them fit for planting with turneps that year; the clods being so very large that they would require so many vicissitudes of wet and dry weather to slack them; but this instrument crushed them small, and the plough following it immediately, the ridges were harrowed and drilled with very good success.

“ I have often made use of it for the same purpose, in the middle of a cloddy field, where it pulverized the clods so effectually, that the benefit of it might be plainly distinguished, by the colour and strength of the two following crops, different from the other parts of the field adjoining on both sides, whereon the roller was not drawn.

“ But

“But crushing has such a contrary effect from squeezing, that if this roller should be used when the land is moist, it would be very pernicious, by unpulverizing it; of which I am so cautious, that sometimes I let the roller lie still, for a whole year together.”

Such a roller, therefore, will speedily reduce the hard clods in the four-foot intervals, at any time in summer, and the pulverized earth being then turned up to the rows on each side by the hoe-plough, will not be liable to become hard again before the next hoeing, when the same earth is to be turned from the rows of wheat into the intervals, which will not annoy the rows, whether the earth is then dry or moist.

As to making attempts to loosen strong land by the plough, while it is wet; that, as the author observes, would serve only to compress it, which is a truth known to every experienced husbandman, and none such do attempt to plough strong land in
that

that condition, with a view of loosening it. This is therefore no valid objection to the hoeing of strong land, which, though not proper to be done while it is wet, can be soon brought into a proper temper for it, upon the return of dry weather.

To the objection relative to drilling, that the drill-plough cannot be introduced in stiff clays, the author should have recollected, that in preparing land for drilling the middle of the new ridges whereon the wheat is to be drilled, is composed of the mould of the former intervals, which having been several times horse-hoed in the spring and summer is not stale and hard like common untilled land, but more resembling land that has been well fallowed; and if the owner thinks it convenient, he may plough up the intervals to form the new ridges, and drill upon the fresh tilth. But for doing this there is no absolute necessity. The shares of the drill-plough, are not above

an

an inch in thickness, and enter only about three inches into the ground. And without doubt a drill may be made to penetrate strong land to this depth. Our author, if he has seen no other drill-plough but Mr. Tull's, may justly think such not strong enough for clays; but there is no difficulty in making one of sufficient strength to drill wheat upon very strong land, prepared in the above manner.

“New methods of husbandry, continues our author, that are to exclude the old, should have every degree of evidence to support them, that ease in the practice, and profit in the issue, are capable of producing. They should not only be more simple and more expeditious in the execution, but more certain and more copious in their produce. If upon repeated trials, any such new method of husbandry was to be propounded, and if the advantages of it were to be confirmed, by the most convincing of all arguments, the

the enrichment of the practisers, then indeed nothing but obstinacy, or infatuation, could be alledged for not relinquishing the old and embracing the new. But if upon an impartial comparison of the merits of the new husbandry, so strongly recommended in books, with those of the old, so tenaciously adhered to by the body of farmers, we find the very reverse of this generally the truth; it is to be wondered at, that a sober and sensible set of men, should adhere to the solid, approved, and experienced maxims of their fathers; and that they should reject this novel husbandry, and refer it to less experienced undertakers; who, like adventurers into new regions, believing the reports of the first discoverers, expect to draw riches from every soil, and make a fortune upon every farm."

Whether the author's account of the hoeing culture may not contribute to the farmers dislike of the new husbandry, and their declining to make any trial of

it, seems not improbable. The six-feet ridges, the manner of forming them, and the subsequent horse-hoeings, described by the author, were as practised at first by Mr. Tull; but that practice upon further experience he exploded, and recommends one more simple and more profitable. This should have been proposed to beginners: let any person read the account given by Mr. Craik of this culture, and they will perceive with what ease it may be performed. Nothing difficult is found there, in the manner of forming the new ridges, which differ in nothing material from the common practice of farmers, in forming ridges of the same size: the horse-hoeings also, are performed in the same manner as common ploughing, and which every ploughman can perform, who can use the common swing-plough. The circumstances of the weeds springing up in Mr. Craik's, is an accident merely local, and by no means incident to this husbandry in general, as

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he has remarked. The profit likewise is such as might encourage any person to make trial of it, who has not been prejudiced against it; and his drill-plough is of so simple a construction, that any person may conduct it at the first trial, and may be made strong enough to drill wheat upon any land prepared by this husbandry.

Notwithstanding the author thus labours to depreciate the horse-hoeing culture, he speaks candidly of the author of it; approves of the principles; and acknowledges that the old husbandry has received great improvements from the new: as in the following passages.

“ But nevertheless, the memory of Mr. Tull ought to be held in the highest reverence by every husbandman, for his improvement of the art of agriculture. It is from him we have learned the great benefit of frequent ploughings to pulverise the soil, which in some situations supply the place of dung. To him the farmer
owes

owes the advantages arising from cleansing and preparing his ground, by sowing of turneps, and improving them by hoeing. It was Mr. Tull who first introduced the drilling of pease, beans, vetches, saint-foin, &c. into field culture, and shewed the advantages of hoeing and keeping them clean from weeds. And it is from him, that the whole kingdom have learned to raise more corn from less seed than ever was thought possible, before he set the example. These are solid and substantial advantages, which have introduced an universal reform in husbandry; though his method of adapting his own practice to his own principles, has not generally obtained." See preface, p. 18.

And p. 175. "It must be acknowledged, that even the old husbandry has received no small improvement, by the discovery of the genuine principles of the new. The advantages of meliorating and pulverizing the earth are better under-

stood, and I believe more generally practised, than formerly; and the grand principle of all, that of frequently stirring, exposing, and enlarging the superficies, in order to supply, in some measure, the place of dung, is a discovery of vast importance.

“ While we hold these principles in view, we cannot go far astray: for all that seems necessary to be done, is to keep our land in such a kind of temperature, as neither to be too hot nor too cold, too loose nor too much bound, too wet nor too dry, too light nor too heavy; but in all our improvements to endeavour to approach as near as possible to that happy mixture which nature has exhibited to our imitation, in the rich meliorated black mold already described; that whether it is wrought by the spade, or barely turned up by the plough, displays its fertility by a voluntary discontinuity of its parts, and a grateful discharge of its fragrance.

“ This

“ This seems to confirm to us the justness of the Tullian principles, by pointing out the necessity of sweetening and meliorating our land, by frequently exposing it to the action of the sun and air, and of separating its parts by repeated plowings. Hence we may learn, that in preparing our land for any kind of grain, we should be less sparing of our labour than of the dung cart, and that of all composts, those of earths with earths are the most natural.”

The author's observation is very just, that the mixture of earths is the most natural, and I may add the most lasting improvement of land ; but the misfortune is, that it cannot in practice be generally introduced. The expence of it, in most cases, is too great for common farmers ; who being unable to make extensive and lasting improvements in that manner, must be contented to correct the imperfections of their land with manures from year to year ; the expence whereof is also

very great, but not necessary to be laid out at once.

Is it not a great recommendation of the horse-hoeing culture, that the land receives by it all the advantages above mentioned? That it sweetens and meliorates the soil, and more frequently exposes it to the action of the sun and air, than can be done in any other method of husbandry. One dressing with dung, as stated by our author, and by other practical husbandmen, costs above five pounds per acre, which is more than three times the whole expence of an acre of horse-hoed wheat.

But to proceed, the objections made by the author to this husbandry, seem to arise from his own ill success in some trials he made of it; and not being particularly informed of the successful practice at large of any other besides Mr. Tull, as may appear by what he says farther, p. 188.

“ And now after all, says he, though *the casualties I have met with*, have rendered

dered me cautious of recommending this husbandry to the general practice, in preference to the old husbandry, yet I cannot be excused, were I to conceal the real advantages that attend it; and they are so well described by Mr. Tull, that I shall give them in his own words.

“First, says he, we can augment our crops by increasing the number of stalks, from one, two, or three, to thirty or forty, in ordinary field land.

“Secondly, by bringing those stalks into ear. For if it be diligently observed, not half the stalks of wheat sown in the ordinary way come into ear.

“Thirdly, by enlarging the size, and multiplying and filling the grains in the ears.

“Thus, adds he, by encreasing the number of stalks, bringing more of them up into ear, making the ears larger, and the grain plumper and fuller of flour, the horse-hoeing method makes a greater

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crop from a tenth part of the plants, than the sowing method can."

"Another advantage," continues our author, attending the new husbandry, and, in my opinion, a very considerable one, is, that in wet summers, if any ears are blighted (or smutty) they stand erect, while the sound ears bend almost down to the ground; so that a man may walk between the rows, and clip off every blighted ear, without leaving one to affect the crop.

"As a very natural conclusion to this account of the culture of wheat in the new husbandry, I shall produce some late experiments, because manifestly derived from, and dependent upon the true Tullian principles. The first is authenticated by the relation of Dr. Watson who has reported an experiment, made by Mr. Charles Miller, son to Philip Miller, esq. the celebrated botanist, by which it appears—That having in the autumn of 1765

planted

planted a single grain of wheat, in the botanic garden at Cambridge; in the spring of 1766 he divided the several plants that tillered from that grain, and transplanted them into fresh earth, by which near two thousand ears were produced from the first single grain. On the second of June, 1766, in order to repeat the experiment, he sowed some grains of the common red wheat, and on the eighth of August he selected a single grain, which had produced eighteen plants; each of these plants were planted out separately; and several of them having pushed out side-shoots, those likewise were divided, and again transplanted. The whole number thus transplanted before the middle of October, amounted to sixty-seven plants; these remained through the winter vigorous, and in the spring of 1767, were again divided and transplanted; and from the middle of March to the twelfth of April, five hundred plants in all were produced, which were suffered to grow

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without any further division, and when ripe were gathered, and the number of ears thus produced from one grain was twenty-one thousand one hundred and nine; some of the plants producing one hundred ears from a single root, and some of the ears seven inches long."

Another experiment mentioned by our author, was made formerly by Thomas Everard, esq. of Southampton, who planted some wheat which he had steeped in a composition of his own invention, viz. stone-lime, nitre, and pigeon's-dung, with rain-water; and then planted the wheat in single grains about ten inches apart. Several of the grains produced sixty, seventy, and from one eighty stalks, with very large ears, full of large corn, many of the ears being six inches long, and had above sixty grains, and none less than forty.—The sediment that remained of the composition, he mixed with four times the quantity of common earth, and laid it up in the shade the whole winter, turning

turning it now and then to incorporate the mixture with the mould; and at the time for planting pease, he caused spade holes to be dug, about six inches apart, and in every spade-hole he put a small quantity of the mixture, in which a garden pea was set, and covered with the common mould. The result was, that the pease grew to an uncommon height, not less than nine feet, were furnished with pods of an uncommon size, and supplied his table with green pease the greatest part of the season.

These experiments shew the wonderful fertility of these plants in rich garden ground, and the advantage of allowing them room, to which probably, more than to the steep, was owing the great encrease of Mr. Everard's wheat: for we see that hoed plants multiply greatly in common unmannured soils, though not steeped.

I have had from ten or twelve to twenty-eight stalks of wheat, each from single grains

grains planted in double rows, and the ears containing about forty grains a piece, upon very ordinary land, hand-hoed: this is a great increase, though far short of some of the above. In broadcast sowing, some grains of wheat produce eight, ten, to eighteen or twenty ears, where they happen to stand single; but in general, wheat sown broadcast, does not produce two ears from each grain sown. For admitting that a middling ear contains only twenty grains, and two such ears forty grains of marketable wheat, this is an increase of forty times the seed sown. But the quantity sown being at an average not less than two bushels and a half per acre, forty times that quantity is one hundred bushels per acre; which is probably near five times as much as is produced annually throughout England, on an average of years and crops, on all sorts of land. By which it appears that four bushels out of five sown are lost, or killed by frost, devoured by birds, &c.

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“In the prosecution of this experiment, continues the author, I cannot help giving this caution. That as it appears both from Mr. Miller’s experiments, and from the experiment above related, that the grains of wheat must have room to extend their increase, care should be taken in sowing, that the seed may be spread as equally as possible, but not too thick. Upon moderately good land, half the quantity of seed thus prepared, may suffice, to what in the ordinary way is commonly sown. I know how hard it will be to persuade the husbandman to practise this frugality: he may, however, safely try a few lands at first, and as he finds the effect, let him continue, or discontinue the practice the future.”

The author here recommends thin sowing, though he before objected to the small proportion of ground planted for horse-hoeing; yet much more seed is allowed in that way than Mr. Everard’s experiment. A gallon of common lam-

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mas wheat contains about 80,000 grains, and six gallons, the quantity usually drilled upon an acre, for horse-hoeing, contains about 480,000 grains, and upon Mr. Everard's land was planted at the rate of 62726 grains per acre; viz. the quantity drilled is above seven times as much as the other. The large size of the ears in the experiment is mentioned, but not the crop produced upon any certain measure of ground. The increase of the horse-hoed wheat, is from thirty to forty gallons for each gallon drilled; and the increase from wheat sown broadcast, not above one third part so much, though the broadcast is manured, the drilled not. This great difference is therefore owing to the hoeing culture, and keeping the land clean from weeds.

There is a method of culture lately introduced, as Mr. Young takes notice, by Dr. Hunter of York, called the alternate husbandry; about three or four yards in breadth is sowed with wheat broadcast,
and

and the same breadth is followed, and thus alternately throughout the field. The following year the wheat stubble is ploughed up for a fallow, and the last year's fallow sowed with wheat. Some manure is beneficial, but not so much necessary as in the common husbandry. The crops obtained this way, are from twenty to twenty-four bushels per acre. The gentleman who introduced this method, recommends it for weak arable land, where manure is scarce.

The author of the Complete English Farmer says that this method is liable to none of the objections which have hitherto retarded the progress of the new husbandry, and yet it seems to promise all the advantages of it; being managed with the same instruments that the common husbandry servants have been accustomed to, that it is ploughed and sowed in the same way, or nearly so, and may be hand-hoed if the weeds become rank.

This, however, is an advantage, only when
the

the wheat is planted in rows; otherwise the same method of hoeing is equally applicable to wheat sown broadcast in the common way.

“That this method, says he, will be profitable where dung is scarce, cannot be doubted: for it is now universally acknowledged, that though tillage has not all the properties of dung, and therefore cannot wholly supply the want of it, yet, where it is properly performed, it does much more towards fertilization than dung of itself can without proper tillage. And we may safely conclude from Mr. Tull’s experience, that the longer any field is cultivated in this manner, the richer and more fertile it will grow.

“I know it will be said by others, because my ploughman has already said it; What can you think to get by ploughing half your lands? does it not double the rent? True, but it lessens the labour and expences. Seed, and time of ploughing and sowing are saved. But he adds, you
do

do not intend to save ploughing; for instead of three times ploughing for wheat, if you plough as often as the weeds spring up, you must plough once a month. Admitted that in summer I may, this then will be six times ploughing one half, which will be equal to three times ploughing the whole; but this will be the greatest part of my expence.

“Dung, where my farm is situated, costs five shillings a load, besides fetching two miles: three shillings a load, and to fetch it six miles; one shilling and sixpence a load, and to fetch it thirteen miles. Dinging an acre, at fifteen loads to the acre, cannot, therefore, be estimated at less than four guineas at an average; one half of which may certainly be saved.

“As to the produce it may be estimated upon good authority, at three quarters upon an acre. This I report upon the credit of a gentleman, who first devised this new method; and I am the rather

inclined to believe the fact from this consideration, that in most inclosures in the common method of husbandry, the furrows and water-furrows take up a considerable space, and produce little or nothing. In this method the furrows are made deep, as in the new husbandry, upon the edges of the intervals, and take nothing from the lands that are sown: these furrows lie open all the winter, by which the superfluous wet is drained off from the wheat; and then, when the spring season returns, they are filled up with fresh earth from the interval, which gives vigour to the vegetating roots, and affords an easy passage for them to spread. This advantage, with the additional tillage, it may be presumed, will ballance the deficiency of ground; especially when it is considered, that Mr. Tull had often, upon two rows in six-feet lands, at the rate of five quarters of wheat on an acre."

This method, it is said above, seems to promise all the advantages of the new
hus-

husbandry, but upon a fair comparison will be found inferior to it. Let us, for example, take an acre of each, and admit that the crops in these two methods are equal, upon equal quantities of land sowed. An acre in the alternate husbandry is half of it sowed with wheat each ear, and the other half of it is fallow. And therefore when it is said, that an acre in this husbandry produces three quarters of wheat, it is to be understood, that a whole acre is sowed with wheat to produce that quantity, and another acre under a fallow: otherwise, if meant of a single acre, half cropped and half fallow, this would be six quarters of wheat upon every acre sowed, at an average. A quantity not to be expected from very good land; whereas the gentleman who introduced this method, proposes it for thin weak land, where manure is scarce. In comparing the two methods, therefore, we must reckon the expence and produce of two acres of the alternate husbandry,

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and compare them to the produce and expence of one acre of the horse-hoed. The crops in the two methods may be reckoned equal, and the expence as follows.

New Husbandry.

	<i>l.</i>	<i>s.</i>	<i>d.</i>
One whole ploughing to form the new ridges, ————	0	5	0
Four horse-hoeings with the hoe-plough, ————	0	5	0
Seed three pecks, at 5 shillings per bushel, ————	0	3	9
Drilling the feed, ————	0	0	6
Hand-hoeing the partitions, ————	0	2	6
Hand-weeding the rows, ————	0	1	3
Reaping, ————	0	3	0
	£.	1	1 0

The hand-weeding is stated high, and twice hand-hoeing, though that is often done but once to a crop. The reaping usually costs about half the price of the sowed wheat.

The Alternate Husbandry.

	<i>l.</i>	<i>s.</i>	<i>d.</i>
Six ploughings of the fallow acre, ————	1	4	0
Dung, ————	1	1	0
Seed, 9 pecks, ————	0	11	3
Reaping one acre of wheat, ————	0	6	0
	£.	3	2 3

The expence of the alternate husbandry } £. 2 1 3
exceeds the drilled, }
Nothing

ON DRILL-SOWING. 325

Nothing is charged for harrowing in either method, which is in favour of the alternate way, that requiring most harrowing. The ploughings also are charged but four shillings per acre, and to the hoed acre five shillings. It is said above, that in the alternate method half the common quantity of dung may be saved; and here only one quarter is charged. Yet it appears that the alternate husbandry, costs double the expence of the drilled; to which must be added the year's rent of the fallowed acre. Hence it is evident, that the hoeing culture is much more profitable than the alternate.

If the land to be fallowed is laid up in one-bout ridges, the tillage may be done cheaper than when laid flat, or into broad ridges; and six ploughings may not be always necessary, though they will more improve the land than four or five, if the weather is favourable. On the other hand, the horse-hoings will not cost so much as above, if the double mould-

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beard plough is made use of, to turn the mould up to the rows, instead of the hoe-plough.

I have charged some dung to the alternate husbandry, in compliance with what is said above, and by the deviser of this husbandry; and no doubt it will be of service in land not over-rich. There is notwithstanding some reason to think, that dung is not necessary in this method, provided care is taken to fallow the land very well, by repeated ploughings and harrowings throughout the seasons, till seed-time. If the dung can be all spared, the expence of this method will be considerably reduced, though not so low as the new husbandry.

The alternate husbandry is supposed to produce three quarters of wheat per acre per annum; which, at five shillings per bushel, is six pounds for each crop; from which deducting three pound three shillings and three pence, the annual expence, there remains two pounds seventeen shil-

lings and nine pence profit per acre, from weak poor land; a profit much exceeding the general run of arable land sown with wheat without manure, or with a small proportion of it; which shews that the crops are stated too high at the three quarters per acre on such land, at an average. On the other hand, such land in the horse-hoeing culture, and no manure, will not at an average produce annually three quarters of wheat per acre. For though good land so cultivated will produce four quarters per acre, and as above mentioned Mr. Craik's crops were so much, and Mr. Tull's often five quarters per acre on his best land; yet, by an account he took one year of the hoed wheat upon his land in general, amounting to above one hundred acres, it appears that the crop upon an average, was only about twenty bushels per acre. And Sir Digby Legard's crops of horse-hoed wheat upon the Yorkshire wolds, was but about ten or twelve bushels per

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acre. He says, indeed, that his crops were so small, partly on account of their want of experience at first, and that when the hoeings were performed better, the land and crops were much improved: though his first crops, imperfectly as they were managed, were much superior to those of the common husbandry there. The wold farmers in that part of the country have no manure for their wheat but the sheepfold, and their average crops of wheat are but four bushels per acre. It is indeed very common in estimating crops to over-rate them, in every mode of husbandry; and therefore I have taken notice of those chiefly that were authenticated by actual measurement.

But though it appears upon the comparison, to be a method inferior to the hoeing culture, it seems, in point of profit, to be preferable to the old husbandry. The method does not much differ from that of the ancient Romans, of fallowing every second year, which is still the practice

tice in some parts of Italy and Switzerland; though their fallowing seems to be very slovenly performed: for in the territory or neighbourhood of Geneva, where it is the common husbandry to fallow their fields and sow wheat alternately, they have exceeding poor crops, viz. but about three bushels in return for one bushel sowed. This we are assured is the common produce of that country by M. De Chateaufieux of Geneva, and that he had no more from his fields, which were cultivated in the manner of the country, and an exact account kept of the produce of them for many years. Nor were these poor crops wholly owing to the native poverty of the soil, but to their bad culture. For when that gentleman, in prosecuting the new husbandry, had brought his land into good tilth, and subdued the weeds, his crops were greatly improved.

Fallowing is beneficial to land, not only in conquering weeds, but likewise

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as it enriches the soil, to a degree equal, or even superior, to a common dressing with dung. But to have this effect the land must be often cultivated, and no weeds suffered to grow rank, much less to run to seed. The horse-hoeing husbandry is a species of fallowing, producing a crop, and at the same time remarkably improving the land; the following instances of this, from Mr. Tull, are very observable, p. 127.

“ A piece of eleven acres of a poor thin chalky hill, was sown with barley in the common manner, after a hoed crop of wheat, and produced full five quarters and a half to each acre (reckoning the tythe) which was much more than any land in all the neighbourhood yielded the same year; though some of it be so rich, as that one acre is worth three acres of this land: and no man living can remember, that ever this produced above half such a crop before, even when the best of
the

the common management has been bestowed upon it.

“ A field, that is a sort of heath ground, used to bring such poor crops of corn, that heretofore the parson carried away a whole crop of oats from it, believing it had been only his tythe. The best management that ever they did or could bestow upon it, was to let it rest two or three years, and then fallow and dung it, and sow it with wheat; next to that with barley and clover; and then let it rest again: but I cannot hear of any good crop that it ever produced, by this or any other of their methods. It was still reckoned so poor, that nobody cared to rent it. They said dung and labour were thrown away upon it. Then, immediately after two sown crops of black oats had been taken off it, the last of which was scarce worth the mowing, it was put into the hoeing management, and when three hoed crops had been taken from it, of turneps and potatoes, it was sown with
barley,

barley, and brought a very good crop, much better than ever it was known to yield before; and then a good crop of hoed wheat succeeded the barley: and then it was again sown with barley, upon the wheat stubble; and that also was better than the barley it used to produce.

"Now, all the farmers in the neighbourhood affirm, that it is impossible but that this must be very rich ground, because they have seen it produce six crops in six years, without dung or fallow, and never a one of them fail. But, alas! this different reputation they give to the land, does not at all belong to it, but to the different sorts of husbandry: for the nature of it cannot be altered but by that, the crops being all carried off it, and nothing added to supply the substance those crops took from it, except (what Mr. Evelyn calls) the celestial influences, and that these are received by the earth, in proportion to the degrees of its pulverisation."

Another

Another example is given by him of the effects of good tillage, p. 21, as follows. "It is of late fully proved by the experience of many farmers, that two or three additional ploughings will supply the place of dung, even in the old husbandry, if they be performed at proper seasons; and the hiring price of three ploughings, after land has been thrice ploughed before, is but twelve shillings; whereas a dunging will cost three pounds. This was accidentally discovered in my neighbourhood, by the practice of a poor farmer, who, when he had prepared his land for barley, and could not procure seed to sow it, ploughed it on till wheat seed-time; and, by means of such additional ploughing, without dung, had so good a crop of wheat, that it was judged to be worth more than the inheritance of the land it grew on."

These examples shew evidently the improving effect of tillage, without the assistance of manure; but as in this last
in-

instance, one crop only was obtained in two years, it might be doubted whether such husbandry would be profitable if continued; we have an example of this in Mr. Maxwells collection; where speaking of this circumstance of the poor farmer mentioned by Mr. Tull, he relates one similar to it, of a poor farmer, tenant to Sir John Paterfon, in Lothian, near Edinburgh; who being likewise unable to buy seed for a field he had prepared for barley, continued to plough it till autumn, and then sowed it with wheat; and reaped so large a crop, that he was thereby encouraged to extend this method of husbandry to his whole farm; by which he came, in some years, to be in circumstances to have purchased the farm.

This has nearly the same advantages with the alternate husbandry. In the latter way the air has a more free passage between the sowed lands, which is a benefit to the crop. On the other hand, when a whole field is fallowed, it may be
more

more conveniently cross-ploughed than in the alternate way. The great disadvantage in both these methods is, that only half the land is sown every year; and admitting that an acre produces three quarters of wheat, when an acre is sown, this is but half that quantity, or twelve bushels per acre, throughout any extent of land cultivated in either of these ways; because, as above observed, in the alternate method only half the land is sown; and in the other the whole is sown but once in two years; and both are loaded with a double rent: the horse-hoed produces a better crop of wheat every year upon the same quantity of land, at a smaller expence, also without manure, or the land being impoverished; but on the contrary it will be improving annually, as appears from experience.

more severely than the other crops, though the
the climate was very dry. The grain is
also in both the methods, but only
the first method is more successful in
sowing the seed in the ground, and the
seed is not so much exposed to the
heat of the sun, when sown in the
first method, than when sown in the
second method. The quantity of seed
sown in the first method is also
less than in the second method, and
the seed is not so much exposed to the
heat of the sun, when sown in the
first method, than when sown in the
second method. The quantity of seed
sown in the first method is also
less than in the second method, and
the seed is not so much exposed to the
heat of the sun, when sown in the
first method, than when sown in the
second method.

It will be seen, therefore, that the
first method is more successful in
sowing the seed in the ground, and
the seed is not so much exposed to the
heat of the sun, when sown in the
first method, than when sown in the
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heat of the sun, when sown in the
first method, than when sown in the
second method.

MISCELLANEOUS
DISSERTATIONS

ON

RURAL SUBJECTS.

Z

On

On the force of running water, &c.—To compute
the quantity of water of a river, brook, &c.—
To make a half-second pendulum for this use.—
Of undershot mills, and dimensions of one mea-
sured by the author.—The velocity and quantity
of water to this mill, and the work done by it.—
Experiments to determine the velocity and quan-
tity of water through different apertures.—A ge-
neral mistake relating to them rectified.—A va-
luable improvement in the wheels of undershot-
mills.—Of overshot-mills, their advantages and
defects.—Compared with undershot-mills from ex-
periments.—Of breast-shot mills.—The dimen-
sions of one measured by the author.—These three
sorts of mills compared.—The quantity of water
that each of them require.—The quantity of water
in the Thames, at Westminster-bridge.—Of the
force, impulse, or momentum, of running water.—
Of the bottomwork of mills and other machines.—
The best method of constructing them, to prevent
blowing.—Of coffer-dams made use of in build-
ing the piers of bridges.—Of Dagenham breach.
—Of Archimede's screw-pump, and how con-
structed.—Of the best kinds of mortar for the
bottoms of water-works.—Of making canals to
conduct water for mills and other engines.—The
manner and expence of making them.

A N

EXPERIMENTAL DISSERTATION

ON THE

FORCE of RUNNING-WATER, &c.

THE extensive use of water for mills and other machines is generally known; but the manner of constructing such machines, and the application of the water to produce the greatest effect, is not sufficiently understood and attended to; the construction of them being, for the most part, left to persons not well skilled in the principles of mechanics and force of running-water. To give some assistance to those who would erect or improve works of this kind, that they may receive the full benefit of the

water, and make the bottom work stronger and more durable than is commonly done, is the intention of this dissertation.

In erecting mills two circumstances are to be well considered, namely, what quantity of water can be obtained from the stream or river to be employed; and to what head or height it can be raised: upon these two the force or effect of the water, and the benefit to be expected from it, principally depend.

To know what quantity of water any river, brook, or stream will yield for this purpose, the depth and velocity of the stream is to be examined, under a bridge, or at some other convenient place, where the banks are perpendicular, and the stream is nearly of an equal depth and velocity. Having measured there six or eight yards in length, and placed marks at each end, then thrown in, a little above the uppermost mark, an apple, orange, or some other light body, that will

will partly sink into the water, and the rest appear in sight above it; and being provided with a half second pendulum, observe what number of vibrations is made by the pendulum, while the body is passing from the upper to the lower mark in the middle of the stream. Repeat this several times, which being accurately done, the medium of these trials will determine, sufficiently exact, the velocity of the water in that section of the river.

A small ball of lead or brass suspended by a thread, whereof the length, from the point of suspension to the center of the ball is 39,2 inches, swings seconds. And one of one fourth part of that length, viz. 9,8 inches, swings half seconds. The thread may be of silk, or very fine brass-wire may be used. Such a half-second pendulum is very convenient for this use; but to make it exact, it is proper, before it is used, to compare it with a good

Z 3 clock,

clock, the pendulum of which swings seconds.

Suppose, for example, that the length of the stream marked out was 22 feet, through which the body passed in 18 vibrations, or 9 seconds: that the breadth of the river there was 12 feet, and depth $1\frac{1}{2}$ foot; these multiplied together, $12 \times 12 \times 1\frac{1}{2}$, the product 264 is the number of cubic feet of water in that section, which passes through it in 9 seconds; this is 44 cubic feet of water per second, that this stream would furnish for the use of the mill, at the time the experiment was made.

Common river or spring-water is found by experiment to weigh 1000 ounces, or $62\frac{1}{2}$ pounds averdupoise per cubic foot; 44 cubic feet therefore weighs 2810 lb. or 1 ton 5 cwt. and 10 lb. at 20 cwt. per ton.

The velocity of such a stream is greatest towards the middle of it, and at the surface

RUNNING-WATER, &c. 343

face of the water ; being somewhat retarded in its motion near the sides by the friction against the banks, and towards the bottom by weeds, stones, &c. And if the water is deep, it commonly runs quick near the surface, and slower towards the bottom : for which reason, in making this experiment in deep water, it is proper to use two balls, fastened together by a thread, one ball to swim at the surface, and the other near the bottom. The top ball will go on foremost till the string is stretched, and then both balls will proceed with the uniform motion of the stream. These balls may be made of wax, and by inclosing in the balls a little lead, or some other heavy matter, the lower ball may be made of the same specific gravity as the water, or a little more ; and the upper ball to swim at the surface of the water, so as a small part of it to be just visible. This is sometimes necessary to prevent the wind having any effect upon it.

In the shallow places of a river, the water runs quick, and slow where it is deep, and the same quantity passes through every part of it; for which reason the quantity found to pass through one section, determines how much passes through every section of the river, for which one experiment accurately made, is sufficient.

When it is known what quantity of water a river will furnish, the next thing to be considered is, to what height it can conveniently be raised. In low flat countries, the highest head that can be obtained, is commonly from 4 to 7 or 8 feet: but in such situations, there is for the most part a plentiful supply of water; and one of the greatest inconveniencies there, is, that the rivers are very subject to be flooded; by which the back water is raised upon the wheels of the mill, and frequently obstructs them; and in winter and rainy seasons, the mills are sometimes totally stopped thereby for many weeks together: for the floods in these
rivers

rivers abate slowly, because the water in them has a slow current.

In hilly countries, the mills are supplied with water from springs or brooks, with which they could do but little work, but that the water there can be raised to a high head, to 12, 14, or 16 feet, and sometimes higher; and they are not obstructed by back-water. The principal inconveniency in them is, that they cannot work constantly in dry weather, but must stand still part of the day, till the water is penned up to a head; and sometimes they have not enough to keep them going for a great while.

Though these defects cannot be wholly cured, either in high or low situations, yet they may in some measure be helped, by a better construction of the water-wheels and bottomwork than they commonly have, as will hereafter be shewn.

When the stream of water that drives a mill passes under the wheels, they are called undershot or groundshot-wheels.

If

If the water is conveyed to the top of the wheel, and falls upon it on the further side, it is called an overshot-wheel. And if the water falls upon the wheel on the inside, near to, or a little above the center, it is called a breast-shot-wheel.

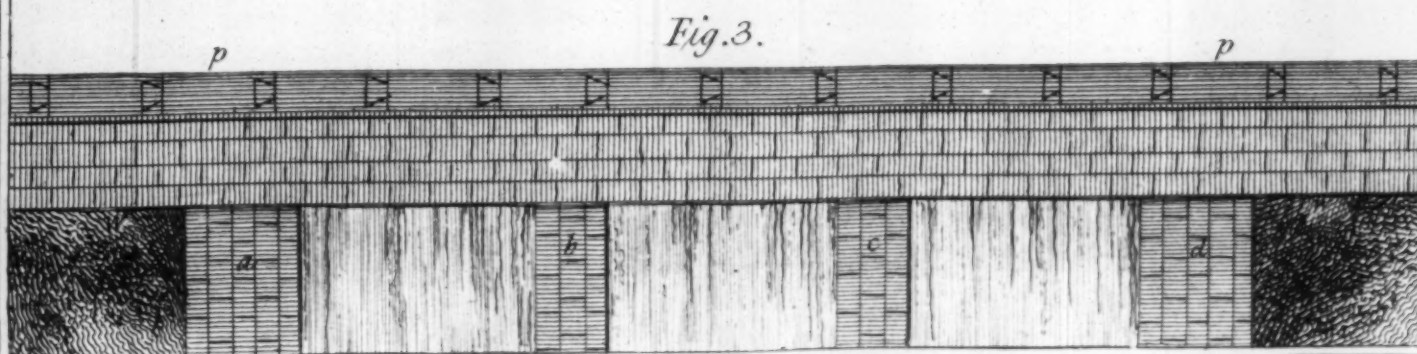
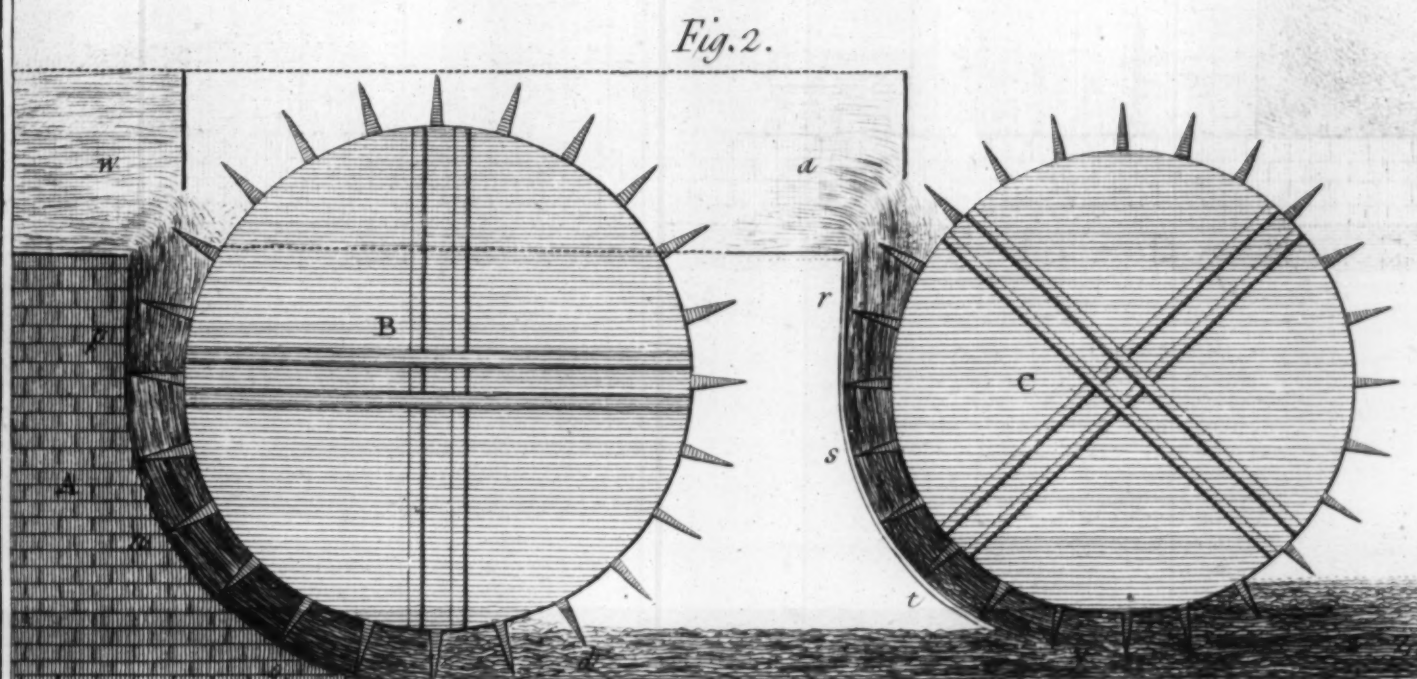
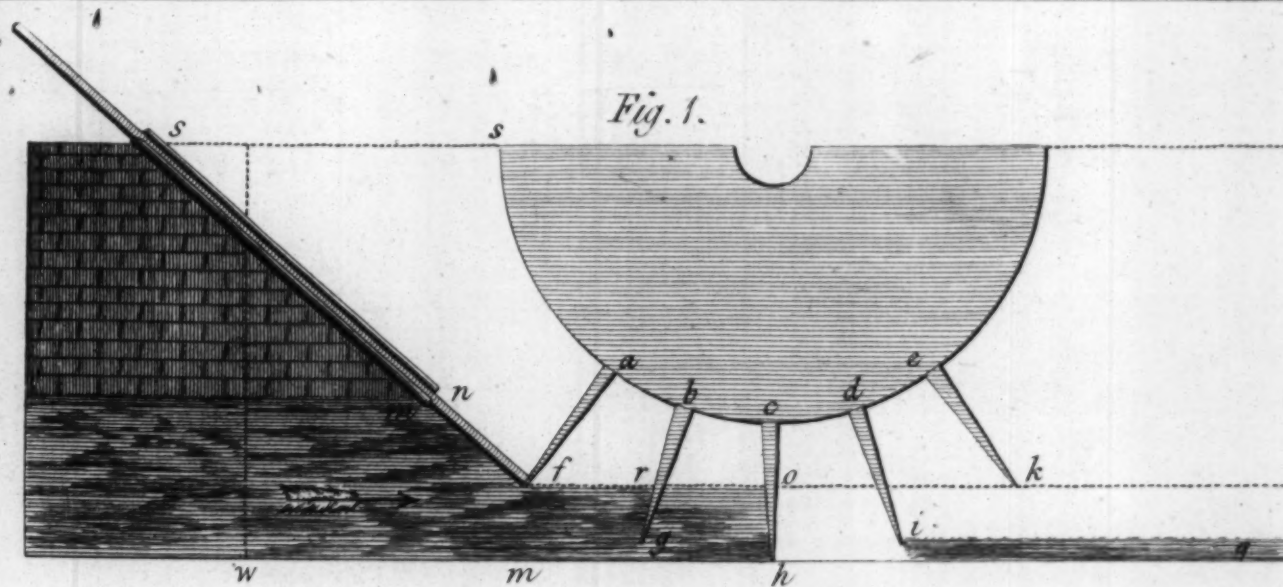
In order to give a clear idea of the effect of water, I shall first describe an undershot corn-mill, as I measured it, together with the owner of the mill; a very ingenious person, well skilled in such works.

This mill has three thoroughs, one for the water to pass under a wheel in the west thorough; another with a wheel on the east side, and a waste thorough between these, to carry off the water, when one or both of the wheels were not at work. The thoroughs are all nearly of the same width, and carried out to the same length, viz. 20 feet from the center of the wheels. These thoroughs are not quite level at bottom, but decline $8\frac{1}{2}$ inches, from the center of the wheels to the

the further end of the thorough; the intention whereof is to carry the water off quick from the wheels, and prevent the back water from rising upon and obstructing them; and to prevent this the more effectually, the thorough is carried out to such a length: for when the thorough is short, the back-water comes up almost to the wheels, and very much obstructs their working: but the back-water being driven out to the further end of the long thorough, it cannot come up to the wheels, nor are they at all or very little obstructed by it, because the pressure of it is at the tail of the thorough, 20 feet distant from the wheels; for which reason it is the best way to make the thorough still longer, and to extend them to 25 or 30 feet below the wheels.

Under-shot mills cannot be built so as to be wholly free from back-water, as the over-shot may; because the under-shot-mills are commonly erected in low flat countries,

countries, where it is difficult to obtain a good head of water, which in such situations would be lowered as much as the bottom work of the mill was raised higher than common. And as the height of the head water is a principal consideration, those who erect mills in such low situations, are obliged to submit to the inconveniency of some back water. For suppose the water in a river can be raised 6 feet above the common surface; when it has rained for some time, the water in the river rises every where; and if that rise is a foot above its ordinary height, there will be in the thorough a foot of back-water, though before there was none. If the head-water could be also raised a foot higher, or to seven feet above the common surface, this would ballance the rise of the back-water, as the rise at the head would cause the water to issue through the penstock with a greater velocity than it did before, and by that means the tail or back-water would be driven out of the



the thorough's. But this cannot be done; the head-water must not be raised higher than 6 feet, to which the mill was at first adopted; but all above that height must be drawn off waste, through sluices placed in the bank above the mill, otherwise it would overflow the banks there, and run into the mill; and also overflow the neighbouring lands.

Plate III. fig. 1. *SW* is the head of water of this mill. *SS*, is the surface of water when at full head, and *SW* the depth or height, 6 feet. *Sm* the penstock, which stands oblique to the wheel, *a, b, c, d*, at an angle of 45 degrees from the perpendicular. This is a greater inclination of the penstock than is common in ground shot mills, and was made so here, that the aperture in the penstock might stand near to the float-boards, and cause the issuing water to strike upon them with the greater impulse.

Snf is the gate of the penstock, which shuts down to the bottom *mh*, when the
mill

mill is not at work; and when it is at work, the gate is drawn up towards f , by which a passage is made for the water to issue through the aperture $f m$, which striking upon the float-boards, as at $c h$, turns the water-wheel $a b c d e$. To shew this the more plainly, the float-boards are represented here deeper from c to h , than their just proportion.

The two water-wheels have each 24 float-boards, fastened perpendicularly to the outward ring or sole of the wheel, $a b c d e$. It is difficult to determine what number of float-boards are the most proper; and at what distance they should be placed upon the wheels, to receive the impulse of the water to the greatest advantage.

If the gate of the penstock, $S n f$, when the water is at a common head, is drawn up to f , and the aperture, $f m$, is then 6 inches deep for the water to pass, and the floats are twice the depth of the aperture, or 12 inches, as the floats $a f$, $c h$, and

a k, and placed upon the wheel at such a distance, that the extremity of the foremost float-board, *a k*, when it rises 6 inches perpendicular shall be at *k*, entirely clear of the current in the thorough; the following float *a, f*, will then just enter the said current at *f*, and the middle float, *c h*, will receive the impulse of the whole current, without being retarded by either of the two other floats. But by this disposition, when the floats arrive to *b g*, and *d i*, some of the water will escape under the floats at *g* and *i*, as *i q*, and be wasted, because it makes no impulse on the floats, while in that position. On the other hand, if the floats are placed near together, the issuing stream cannot strike fully against the middle float; and the current will be obstructed by the foremost float, while it is rising. A medium number, therefore, should be chosen, which seems to have been nearly observed in the floats of these wheels, as this mill does as much work as most others, that have

wheels

wheels of the same dimensions, and the same head of water.

feet. in.

The diameter of the west wheel is 11 2

The depth of the floats, 0 10

Diameter, including the float-boards, 12 0

The diameter of the east wheel is 10 10

Depth of the floats 0 10

Total diameter of this wheel, the floats in-

cluded, is 11 8

The float-boards of both wheels are of the

same length, viz. 3 2

The west wheel, with one part of the tackle, drives a pair of French mill-stones, for grinding wheat; and with the other part drives two bolting mills, to dress the flour.

The east water-wheel drives a pair of French mill-stones, for grinding wheat, and one pair of Cullen or Peak mill-stones, to grind barley for hog-meat.

The full head of water that this mill can pen up to, is 6 feet. With this head, or an inch or two lower, the west wheel

wheel grinds 5 bushels of wheat an hour, when the gate of the penstock is drawn up $6\frac{1}{2}$ or 7 inches; and at the same time works the two bolting mills, and dresses the flour. The bolting-mills are light, and do not require much force of water to drive them. When the water is kept constantly to the full head of 6 feet, the west wheel will grind 5 bushels of wheat an hour, when the gate of the penstock is drawn up only $5\frac{1}{2}$ inches; for there is some difference in the manner of grinding. A person who occupied this mill, some short time before the above mensuration, kept up a good head of water, and when the mill was at work, drew up the gate of the penstock 9 inches, which made the mill go so fast that the flour was heated and damaged. In general, this mill, with a full head, and the gate drawn up about 6 inches, will grind 5 bushels of wheat an hour, and dress the flour at the same time.

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It

It was formerly the custom, at the distance of 40 miles or more from London, to use Cullen millstones, with which this mill would grind 8 bushels of wheat an hour, without dressing the flour, which was not done than in the country. It was then ground only into meal, and the meal sent to London, and dressed there. A mill for grinding wheat, if worked every day, should have two pair of French millstones, one pair to work, while the other is dressing and cooling, which is done about once a week.

In order to calculate the quantity of water expended in driving an undershot-mill, it has been supposed, that the stream issuing through the aperture in the penstock, entirely fills the aperture during the time of its running; and that it issues with the same velocity that a body acquires by falling in vacuo from the the same height that the center of the aperture is from the surface of the water above it.

It

ON THE FORCE OF
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It has been found by experiment, that a body in vacuo, accelerated by gravity, falls 16,0913 feet, or nearly 16 feet and 1 inch per second; but will not in that time descend so far in air, being in some degree retarded by the resistance of the air; in which its fall may, in even numbers, be reckoned at 16 feet per second.

The velocity of water issuing through equal vertical holes, is in a subduplicate ratio of the height of the water above the center of the holes, viz. through holes at four times any depth, the velocity will be double to that through equal holes of that depth below the surface of the water. Thus through a hole at 16 feet deep, the velocity is double of that through a hole of 4 feet deep.

The velocity of water through an inch square vertical hole, the center of which is two feet under a surface or head of water, kept constantly to that height above the center of the hole, ought to

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 be nearly 11,34 feet per second. And if the
 hole is, during that time, quite filled, the
 quantity expended will be the same, as if it
 was a solid body of ice, having a base an
 inch square, and 11,34 feet in length, con-
 taining 136,08 cubic inches. But Dr.
 Desaguliers found, by repeated trials,
 that an inch square hole, at two feet un-
 der the surface, yielded but 5,06 tons an
 hour; which multiplied by 35,68, the
 cubic feet in a ton of water, is 180,5408
 cubic feet an hour, which is 86,6592 cu-
 bic inches, or, 7,2216 feet in length per
 second, that passed through this square
 hole, by the experiment; but according
 to the rule of falling bodies, it ought to
 have yielded 11,34 feet per second.

Also by Marriotte's experiments, a
 round hole of 3 lines diameter, the center
 of which was 13 Paris feet below the sur-
 face of the water, gave 14 Paris pints in
 a minute, whereof 35 made a cubic foot,
 Paris measure. See his Hydrostatics, p.
 167.

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A Paris foot is to the English foot as 1068 to 1000, and therefore 13 Paris feet are equal to 13,884 English feet; and by the rule, the velocity of the water issuing from a hole at this depth under the surface is $\sqrt{13,884 \times 64,2882}$, or 29,876 English feet per second. But, as above there issued through this hole a cylinder of water of 3 lines in diameter; and 19,54908 Paris feet in length, in a second, which is 20,87841 English feet in length in a second, by experiment, instead of 29,876 English feet per second, which this hole should have given by the rule.

The first of these experiments gives a little less, and the second gives a little more than $\frac{2}{3}$ of the quantity determined by the rule of falling bodies. We may, therefore, take the medium of these two, as very near the quantity that issues in a second through small orifices; and that it is $\frac{2}{3}$ of what they should give by the rule.

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It is a material enquiry, from what cause it happens, that the real quantity given by such small orifices, falls so much short of what they ought to give by the rule; a circumstance not taken notice of by those who have tried such experiments, but who in general suppose that the quantity given corresponds with the rule; or do not assign the cause why it is otherwise.

The deficiency must arise either from the velocity, or the quantity, falling short of the rule. That the velocity corresponds nearly with the rule, appears from jets of a moderate height, which when well executed, rise very near as high as they ought to do by the rule. And likewise because the quantity given by holes of equal dimensions, is nearly as the square roots of the heights of the water above them, which also corresponds with the rule.

And that the deficiency is in the quantity, and not in the velocity, appears still more

more clearly from an experiment related by Mr. Clare, in his Motion of Fluids, p. 89. "An experiment, says he, was accurately made by Dr. Desaguliers, of the running of water horizontally, through a hole $\frac{1}{2}$ of an inch in diameter, the center whereof was just 4 feet below the surface of the water, of a vessel kept always full. This vein of water so contracted itself, that at half an inch distance from the hole, that is where it seemed thinnest, it all ran through a hole of half an inch diameter, made in a tin plate. By afterwards weighing the whole body of the water produced, and reducing it to a cylinder of half an inch diameter, or something under, it appeared, that the velocity of the water issuing, was the same as a drop of water would have acquired in falling the height of 4 feet in vacuo. In this case therefore, we are not to call the hole or aperture $\frac{1}{2}$ but $\frac{4}{5}$ of an inch in diameter; and that we may always consider as a hole without friction, with

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which

which the theory will sufficiently correspond, it is to be given.

It is also observable, that water issuing through a small hole, does not run in a full body, equal in dimensions to the area of the hole, as a body of ice would pass that exactly filled the hole. But the water issues with a circular or twisting motion through small holes, and somewhat similar in larger; and by that means they do not give the full quantity that might otherwise be expected, if they ran with a full stream equal to the hole. It was for this reason, and partly from the friction of the water against the sides of the hole, that in the above experiment made by Dr. Defaguliers, the quantity was so much short of the rule.

The areas of circular holes are to each other as the squares of their diameters; as in the present case, the diameter of the hole in the vessel being 5, the area is 25, which is the quantity it should have given; and the diameter of the hole in the

inches

tin

tin plate being 4, the area is 16, which
 is the quantity it did give; that is, the
 quantity from the vessel was about $\frac{1}{4}$ of
 what it ought to have given, agreeable to
 the above experiments; and the defi-
 ciency was in the quantity, and not in
 the velocity. The cause of this great de-
 ficiency in small holes, is principally from
 friction, and the twisting motion.

In large apertures, the friction is not
 proportionally so great, as in the small;
 but in these the deficiency is also very
 great from other causes. The large body
 of water necessary to supply such aper-
 tures, must come from some distance all
 round them, and meeting at the aperture
 in all directions, causes an irregular and
 intestine motion there, which obstructs
 the free passage of the water, so that the
 deficiency is often as great as through the
 small holes.

That we may apply this to the above
 undershot-mill, whereof the head is 6
 feet high, the gate being drawn up 6
 inches,

inches, and the aperture 38 inches wide, the area through which the water passes to the floats, is $38 \times 6 = 228$ square inches, or 1,58333 square foot. And as the center of that aperture is 5 feet 9 inches, or 5.75 feet under the surface, the velocity of the water is 19,2647 feet per second by the rule, which multiplied by the area of the aperture 1,58333 gives 30,44127 cubic feet for the quantity of water expended per second; but, as we have shewn above, the real quantity is but about $\frac{2}{3}$ of this, viz. only 20,29418 cubic feet per second, which is 2038,6453 tons an hour, to grind and dress 5 bushels of wheat.

This is a much greater quantity of water than is necessary for overshot and breastshot-mills, to grind the same proportion of wheat; and if they required as much water, very few mills would be erected. But undershot-mills being built upon rivers, have a large supply of water, through the greatest part of the year.

This

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This mill, which is upon a small river, has water enough to work constantly about half the year, and during that time grinds about 20 loads of wheat per week, 40 bushels to the load, 9 gallon measure: but the other half of the year, can grind and dress but about half that quantity; as there is not water enough then to keep the mill constantly employed; but all the gates must be frequently shut down, till the water rises to a full head.

This inconveniency would wholly, or in a great measure, be removed by a different construction of the water-wheels, which if made 18 or 20 feet diameter, and the floats 6 feet wide, this mill might be worked constantly throughout the year, grind and dress 5 bushels an hour, with the quantity that is now reckoned short water; and do more work with a full supply of it, than can be done at present. But the improvement would be still greater, if this was made a breastshot-mill, as will appear hereafter,

In order to determine the force of water upon the wheels of a mill, it is necessary to know their velocity: for that purpose I measured the velocity of the west wheel of this mill, by a half second pendulum, and found, by repeated trials, that, when at work with a full head, it revolved full 18 times in 60 seconds; and I have found that the wheels of some other corn-mills of nearly the same construction and diameter, revolved at the same rate when in full work, with an equal head of water.

The middle of the aperture being 3 inches, the greatest impulse of the issuing water is at that height upon the floats, which being deducted from 12 feet, there remains 11,75 feet for the diameter of the west wheel, and the circumference at that diameter is 36,9285 feet, which as above revolves 18 times in 60 seconds, or 11,0786 feet per second, for the velocity of the wheel, which is above half the velocity

locity of the water, as it issues from the aperture in the penstock.

Monfieur Parent's *maximum* is, that an undershot-wheel can do the most work when its velocity is equal to one third of the velocity of the water that drives it. This would be nearly true, if the aperture did give the full quantity of water, with the velocity of bodies falling in vacuo. But, as it has been shewn above, that though the water issues through the penstock with that velocity nearly, yet as the issuing stream fills but $\frac{2}{3}$ of the aperture, it can have but $\frac{2}{3}$ of the effect of the full quantity, and therefore that an undershot-wheel can do the most work when the velocity of the wheel is equal to one third of the velocity of the issuing water, according to the rules of falling bodies, and two thirds of the quantity of water that the aperture would give, if the issuing water quite filled the aperture.

Computing, therefore, the effect of water through such apertures, without regarding

regarding the quantity they give, Mr. Parent's rule will be right, that an undershot-wheel can do the most work when its velocity is one third of the velocity of the water that drives it.

But if we take the quantity and velocity both into the account, the water in that case has the greatest effect when it moves with only twice the velocity of the wheel. Agreeable to this, Marriotte says, p. 136, that the wheels of the mills upon the river Seine, at Paris, have at their circumference but half the velocity of the running water that strikes against them. And that the same proportion is observed in the wheel of the pump of the Samaritain. For here the impulse is made by the full quantity of water; every foot square of the float-boards, is impelled by a body of water of the same dimensions; whereas the body of water issuing through a penstock, upon the floats of an undershot-wheel, is really

really but $\frac{2}{3}$ of the dimensions of the aperture, as we have shewn above.

There is such a large supply of water in rivers, that the mills, as they are usually constructed, cannot make use of it all, in a full water, and much of it is then drawn waste through the waste thorough of the mill, and through sluices placed for that purpose in the banks above the mill. But in floods, all these are not sufficient; the water rises every where in the river, and the wheels are stopped by the back-water.

This is a great abatement in the value of mills so situated: for sometimes they cannot work for weeks, and even months, together. Any cheap method, therefore, that can be contrived to keep these mills at work in a full water, and in floods, must be acceptable to the owners and occupiers of such mills.

The float-boards of such mills are commonly but about a foot deep, and for that reason cannot drive out two or three feet deep of back-water, but by drawing the
gate

gate of the penstock higher than common, and enlarging the aperture for the passage of the water, that may be done, provided the float-boards of the wheels are adapted to the aperture. This may be done by making sliding float-boards, to be drawn out or put in occasionally. The sole of the wheel should be placed nearer the center; and in floods, the float-boards should be drawn all out alternately. As suppose the wheel has 24 floats in a common water, the boards of 12 of them are to be taken out in time of floods. It is not necessary that all the boards of these 12 remaining floats should be moveable, those next the circumference of the wheel, of about a foot deep, may continued fixed, and if boards are made to slide on about two feet more, may be sufficient.

This method is yet very uncommon, though a great improvement; but as some persons may doubt the effect of it, and whether a back-water of two or three feet

feet can be driven out in this manner. I shall shew the force of the head-water when this alteration is made; first premising, that the floods in the Thames seldom rise much higher than two feet above the level of a common full-water: but in rapid rivers, where the floods rise to a great height, they are seldom of such long continuance as to render such precautions necessary, if the mills are erected in a proper situation. *Suppose* the back-water is two feet deep upon the wheel, and the floats are also made of that depth by additional or sliding-boards. Draw up the gate of the penstock two feet; the middle of the aperture will then be 5 feet below the surface of the head-water, the quantity expended will be 6541602 cubic feet per second, issuing through the penstock with a velocity of 17.92877 feet per second; but turns the wheel with only about half that velocity, or 8.96438 per second; and being discharged at that rate from the

B b wheel,

wheel, has a velocity more than sufficient to drive out the back-water.

Again, if the back-water is 3 feet deep, the floats made suitable, and the gate drawn up 3 feet, the center of the aperture will then be $4\frac{1}{2}$ feet below the surface of the head-water. The quantity discharged is 8,9722 cubic feet per second, issuing at the aperture with a velocity of 17 feet per second, and half that velocity, viz. $8\frac{1}{2}$ feet at the wheel and thorough.

Hence it appears, that by drawing up the gate 2, 3, or more feet, there is water issuing from the aperture with a sufficient velocity to drive out the back-water, and the same at intermediate distances, if the floats are made of a proper depth, by the sliding-boards: by which the motion of the millstones are likewise regulated: as it may also, where they go too fast, by setting to work another pair of millstones, or by drawing off some of the head-water through the waste-gates in the banks above the mill.

Over-

Overshot mills are very different from those we have been treating of. They are not supplied with near so much water as the undershot-mills, but that deficiency is in some measure compensated by wheels of a larger diameter; by their having buckets to the wheels, which retain the water through part of their revolution, and give them an impulse both by its weight and velocity; and also that they are not obstructed by back-water, if erected in a proper manner.

This circumstance is not always duly attended to, in building these mills; for back-water is a greater obstruction to them than to the undershot; and cannot be drove out by their head-water, as it may in the undershot.

To explain this it is to be observed, that water falls on the inside of the wheel of an undershot-mill, and it revolves in the direction *abcde*, Fig. 1. but the water falls on the outside of an overshot wheel, which causes it to revolve in a

contrary direction; by which means it drives the back-water up towards the head, where it is continually pressing upon the buckets, and obstructing the revolution of the wheel. For this reason the mills should be built high enough to avoid any back-water, and may be easily done in their first construction; the high, or quick declining ground, upon which overshot-mills are erected, generally admitting of the head-water to be raised to such a height, that raising the bottom work above the level of the back-water, will not make much difference in the force of the water that falls upon the wheel; or may be compensated by larger buckets, or a little more breadth in the wheels.

Overshot-mills require a great deal less water than the undershot to do the same work. Mr. Beighton describes an overshot-mill at Nuneaton, in Warwickshire, as a good one. The water-wheel is 16 feet in diameter, and has 30 buckets,

17 $\frac{1}{2}$ inches wide, 19 inches deep, and 4 broad at the bottom, and their distances from each other at top, is the same as the width, viz. 17 $\frac{1}{2}$ inches.

The water is raised 23 $\frac{1}{2}$ feet high above the bottom work of the mill; and the head-water is 7 $\frac{1}{2}$ feet above the top of the wheel. At the bottom of this head-water there is a trough or trunk, 12 inches square within. And in the trough there is a penstock, with a gate or draw-board, 10 $\frac{1}{2}$ inches broad and 12 inches high; and when the mill is at work this gate is drawn up about 2 inches high: so that the aperture is 10 $\frac{1}{2}$ $\times$ 2 inches, or 21 square inches area. The bottom of the trunk is level with the top of the wheel, where the water is delivered into the buckets, about 6 feet from the penstock. The water-wheel makes 8 revolutions in a minute. It has a face-wheel fixed upon the same shaft or axis, with 48 cogs; and this turns the lanthorn or trundle that is fixed to the upper mill-

stone. The trundle has 9 rounds. So that for every revolution of the water-wheel, the mill-stone goes round 5,33 times; and consequently 42,4 in a minute.

This mill, Mr. Beighton says, will grind 30 bushels of corn in 12 hours, the bushel being $\frac{1}{3}$ part more than the Winchester. There are another pair of smaller mill-stones, that may be worked by the same water-wheel. These, he says, are used for grinding wheat for fine flour; by which it seems the larger pair are not for that use, but for grinding other corn; and he says nothing of bolting or dressing the flour; bolting-mills being of later invention, except near London.

The surface of the head-water being 7,5 feet above the top of the wheel, the velocity of it is 21,9581 feet per second, which multiplied by 21 square inches, the area of the aperture, produces 3,2022 cubic feet per second issuing through the penstock by the rule, but by experiment only

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only $\frac{2}{3}$ of that quantity, viz. 2,1348 cubic feet of water per second, to drive this mill.

The above described undershot-mill, would grind 8 bushels of wheat an hour, 9 gallon measure, with Cullen or Peak-stones, which is 288 quarts. The Nuneaton mill ground $2\frac{1}{2}$ bushels, or $82\frac{1}{2}$ quarts an hour, probably in the same manner, and with the same kind of mill-stones. The first required 20,2941 cubic feet of water per second, and in an hour 73058,76 cubic feet to grind 288 quarts; and the latter required 2,1348 cubic feet, per second, and in an hour 7685,28 cubic feet, to grind $82\frac{1}{2}$ quarts. But the Nuneaton-mill, to grind the same quantity as the undershot, viz. 288 quarts, would require 26829,528 cubic feet an hour. The undershot-mill therefore requires almost three times the quantity of water, that this overshot-mill does, to perform the same work, in the same time.

The disproportion would be still greater if the water employed to drive the overshot, was applied in the manner as in a sweep or breastshot-mill, and with as high a head : for even in the low heads the advantage of the breastshot is considerable. I know a corn-mill that has two water wheels, and a low head of water, not quite five feet high : both wheels were formerly groundshot ; but some years ago the occupier had one of the wheels altered to a breastshot. With this wheel before it was altered, the mill ground scarce 4 bushels of wheat an hour ; and since the alteration it grinds 5 bushels an hour. No alteration was made in the diameter of the wheel ; only instead of the water passing under the wheel, as it did before in the same manner as in other groundshot-mills, it is now brought to the top of the wheel, in a trough four feet wide and about two feet in the water. There is a notch or hole across the bottom

I shall

of the trough, the whole breadth of it, through which the water falls perpendicularly upon the floats, a little below the center of the wheel. This wheel requires now much less water than before, though it does more work.

A groundshot paper-mill, that some years since had not near water enough in dry weather, and the owner was then obliged to shut down the gates great part of the day, in order to raise a head of water to work the rest of the day, this being then a groundshot-mill; but the owner having altered it to a sweep or breastshot-mill, there is now water enough, not only to work the mill constantly, but commonly more than is necessary: so that some water is drawn off waste every day. I saw this mill in full work, and at the same time some water drawn waste, in one of the driest seasons that I remember: and as this is one of the principal modern improvements in the water-wheels of mills, I shall

shall give a more particular description of it; agreeable to the dimensions of the wheels and bottom work of a paper-mill of that construction, which I measured.

Pl. III. fig. 2. is a transverse section of the two water-wheels and breast-work, &c. of a paper-mill. The breast-work is of brick, built in a circular sweep, p, n, o . B, is the upper wheel, 8 feet 10 inches long, and 7 feet 5 inches in diameter, exclusive of the floats. The floats are 7 inches high above the wheel, 12 inches distant at top, and 25 in number. They are made feather-edged, being one inch thick at top, and $2\frac{1}{4}$ inches thick next the wheel.

This mill has two water-wheels of the following dimensions.

	feet.	in.
The length of the upper wheel B,	8	10
Length of this wheel and floats, exclusive of the rings at the ends of it,	8	3
Diameter of the wheel, including the floats,	8	0
Depth of the float-boards above the barrel,	0	7
The streight sides of the floats, upon which the water falls, stands perpendicular to the barrel.		

The

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feet. in.

The length of the lower wheel C, including the rings at the end, 10 4

Diameter of this wheel, including the floats, 7 2

This wheel has 22 float-boards, each in length 9 9

The float-boards are 12 inches distant at their tops, and are 7 inches high above the barrel. They are feather edged, and of the same thickness as those of the other wheel.

Both wheels are barrels, made of boards one inch thick.

The shafts of each wheel are 14 inches square; and the iron gudgeons in the ends of the shafts, upon which the wheels turn, are 3 inches in diameter, and extend 3 inches beyond the ends of the shafts.

The breast-work, A, is of brick, with a circular sweep *p, n, o*, built so as to fit exactly the floats of the wheel, B, which almost touch the brick-work of the breast-work, and brick pavement below, that no water may escape there, and be wasted. The lower wheel C, is inclosed by

by a sweep made of boards, about an inch thick, at *r s t*, which the floats almost touch, to prevent any water being wasted from the wheel.

The thorough is paved with brick, and widens from the lower wheel, to 12 feet, to give the water a free vent; and the bottom has a drip or fall, from thence to the lower end of the thorough, of 6 inches: when the water is all shut in at head, the pavement is dry. And when the head-water is at full height, it is nearly 8 feet and 1 inch above the surface of the back-water. It is necessary that such breastshot-wheels, should stand as clear as possible of back-water; which if it was of any considerable depth, could not be driven out of the thoroughs, by the thin sheet of water that works these wheels; as it may in undershot-mills.

The water to drive these two wheels, comes from a small branch of a river, in the bank of which there are two sluices, each four feet wide, the gates whereof are com-

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commonly drawn up about a foot, to keep both wheels going.

The water is conveyed to the wheels in a large trough, the top whereof is about an inch higher than the tops of the wheels; and when they are at work, the trough is kept quite or very near full of water, which is then 26 inches deep next the wheels, the trough there being of that depth. The surface of the water in the trough, when quite full, is 8 feet and one inch higher than the pavement of the thorough.

In the bottom of the trough are cut two long notches or holes, one over each wheel, and of the length of the float-boards. The notch to the upper-wheel is 8 feet 3 inches long, and 6 inches wide; and the notch at the lower wheel is 9 feet and 9 inches long, and 5 inches wide. There are sliding shutters to each notch, which are shut close or open by levers or handles, by which these notches or openings are made wider or narrower at pleasure,

pleasure, and more or less water is thereby let down upon the floats, as may be found necessary. It is very rarely, if ever, necessary to draw the shutters quite back, and open a passage for the water through all the hole at once. The quantity of water necessary to turn the wheel being more or less, in proportion to the work to be done by it; it is commonly sufficient to draw back the shutter, and open a passage for the water about 2 inches wide, sometimes more.

The trough is 26 inches deep, and the bottom of it about 2 inches thick; and the water, after it has passed through the hole at the bottom of the trough, falls 18 inches before it touches the float-boards; the height of the surface of the water, therefore, above the first float-board it touches is about 3 feet and 8 inches, whereof it falls 18 inches in the air. It has not been determined by accurate experiments what proportion of the head should be allowed to the depth

in

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in water, and to its fall from thence upon the float-boards in air. But as this mill performs well, it seems that the proportion allowed here, is nearly the best to produce the greatest effect.

The lower wheel is of the same height at top as the upper one, but does not go so low as the pavement by 10 inches, (being so much less in diameter than the upper one) by this means the water discharged from the upper wheel has a free passage under the lower one, without obstructing it. To compensate for the lower wheel being 10 inches less in diameter, it is made 18 inches longer than the upper one. The water when discharged from the upper wheel at *d*, runs from thence down the thorough, in a thin sheet to *y*, and from thence the water from both wheels unite, and proceed to *z z*.

It is found by experiment, that a hole in the bottom of a vessel gives more water, than an equal hole in the side of it, the surface of the water above both holes
being

being of the same height. This is partly occasioned by the change of the direction of the water, which falls, as it is naturally inclined to do, directly perpendicular through the hole at bottom; but in passing through the vertical hole it must alter its direction, and issue out horizontally. And hence the water in breast-shot-mills makes a greater impulse upon the floats, than it does in the undershot; and also has a greater effect, because it acts upon the floats of the breastshot both by its weight and impulse, but acts upon those of the undershot by its impulse only, its weight being wholly upon the bottom of the thorough.

When the water is 2 feet deep in the trough, it will issue through the notch or aperture at bottom with a velocity of 11,3347 feet per second by the rule, but by experiment only $\frac{2}{3}$ of this, or 7,5564, feet per second. And admitting that the hole at bottom is 2 inches wide, and the length of it for the upper wheel being 8 feet 3

6 inches,

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inches, the area is 198 inches of water continually passing, which multiplied by the velocity, produces 10,39 cubic feet per second, to drive this wheel.

If we compare the quantities of water necessary to work these mills, per second,

	Cubic feet.
The undershot requires per second	20,294.1
The overshot Nuneaton mill	2,134.8
The breastshot	10,39

Much of the water that falls upon an overshot-wheel, dashes away on each side, and is wasted; for which reason the Nuneaton mill did so little work, grinding only 30 bushels of corn in 12 hours, or $2\frac{1}{2}$ bushels an hour. Whereas a breastshot, where none is wasted, would do more work, with a wheel of the same diameter.

It appears here that the breastshot wheel requires a great deal more water than the overshot; but it is to be considered, that the water which drives the overshot-wheel, strikes upon the floats,

C c

with

with almost double the velocity that it does upon the floats of the breastshot : and likewise that the diameter of the overshot-wheel, is near twice the diameter of the breastshot ; both these make a great difference in the effect of the water upon those wheels ; much greater than is ballanced by the greater length of the floats of the breastshot-wheel. Add to this, that the undershot in the present comparison does a great deal more work ; and that the overshot, to do as much work as the undershot, requires about one third as much water.

When it was proposed to bring the Cowley stream (one of the branches of the Uxbridge river) to London, for a supply of water to the inhabitants, Dr. Defaguliers measured a section of it, under the bridge, and found the velocity of the stream there to be one foot per second, and that through the section, there passed 60 cubic feet of water per second. So that if this stream was raised to a head 6 feet

feet high, it would drive three undershot wheels, such as I have above described.

Mr. Labalye, in his account of Westminster-bridge, says, that the river Thames is there nearly 1220 feet broad. That at common low water, (when not kept up by the tide, nor swelled by floods) in the ebb channel near the Surry shore, the water is about 8 feet deep, and in the flood channel, 6 feet deep near the Westminster shore; and that upon the shoal between the two channels, the water is seldom more than 4 feet deep at a common low water. The medium of these is about 6 feet deep of water, in that part of the river.

Westminster bridge has 13 arches, and the whole opening or water-way between these arches is 820 feet, through which the water all passes at the time of ebb. The fall of water, occasioned by the piers, is then but $\frac{1}{10}$ of an inch, under the arches; and the velocity of the water at

the surface, barely $2\frac{1}{4}$ feet per second just above and below the bridge.

As the water at the bottom and sides runs considerably slower than at the surface, and cannot be much accelerated by such a small fall as $\frac{3}{10}$ of an inch, the mean velocity of the river at that place, is probably not more than $1\frac{1}{2}$ foot per second, at which rate the quantity of water that passes at such times through Westminster bridge, in $820 \times 6 \times 1\frac{1}{2} = 7380$ cubic feet per second. So that if the river Thames, at a common water, was all raised to a head of 6 feet high above the the apertures, it would drive 369 such undershot-wheels as above described.

In the water-works at London bridge, the water-wheel under the arch next the city, is 20 feet diameter. It has 26 floats, each 14 feet long and 18 inches deep. The velocity is 11,4166 feet, and of the wheel 5,1666 feet per second: so that the wheel moves with nearly half the

and will do more work with the same

velocity of the water, or as 1 to 2,2, agreeable to what we have shewn above, and that it ought to do, by the rule of the congress of bodies ; and would be more nearly so, if the velocities could be measured exactly, which in such experiments it is not easy to do ; and in calculations upon this subject respecting mills, is not necessary.

By the foregoing directions may be known what quantity of water any river, brook, or stream will yield ; for having taken the level of the place to which it is to be conducted, and what height can be obtained for the head of water ; it may then be determined which is the most proper kind of mill to erect there, an undershot or breastshot, to do the most work. As to overshot-wheels, it is not advisable to erect them : for where there is a head sufficient for an overshot-wheel, a breastshot one may be erected, which is preferable to an overshot in several respects, and will do more work with the

same quantity of water. We have seen, by the examples above mentioned, the advantage gained by lengthening the float-boards, as in the breastshot-mills, though the diameter of the wheels is less than common; but where there is such a fall, that the wheels may be also made of a large diameter, the advantage of breastshot-wheels is greatly encreased beyond what is obtained in overshot-mills.

The examples given above of the force of water, is in regard to corn mills, these being the most common and useful; but as the same is applicable to many other useful purposes, I shall next take notice in what manner the impulse, force, or momentum of running water is to be determined generally, and however applied, to grinding corn, or performing any other work.

The impulse or momentum of water, is in proportion to the product of the square of the velocity multiplied by the area of the aperture. As in the described
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undershot mill, the velocity through the aperture was found to be 19,2264 feet per second, the square of which is 369,6534, to be multiplied by the area of the aperture, 1,5833 square feet, but as we shewed that by experiment, only $\frac{2}{3}$ of the aperture is filled by the issuing water, viz. .6333, this multiplied by the square of the velocity produces 234 cubic feet, at 62 $\frac{1}{2}$ pounds per cubic foot, is 130 hundred weight, for the force or impulse of the water.

The force of this impulse is not wholly spent upon grinding the corn, but a considerable part of it is lost by friction of the gudgeons of the water-wheel, and of the cogs and other parts that touch and rub against each other. The friction is greatest in such machines where pullies, ropes, and screws are employed; and in general, the friction in compound machines abates about $\frac{1}{3}$ of the power by which they are worked. Thus in the present case, the aperture of the penstock of the undershot-

wheel being 6 inches, we are not to estimate, that the whole force of the 6 inches deep of water is exerted in grinding the corn, but that 2 inches, or one third of it, is exerted to overcome the friction of the wheel and other parts of the mill.

There is one great advantage in breast-shot-mills above the undershot, that the bottom work of the latter is vastly more expensive at their first erection, and afterwards keeping it in repair, than that of the breastshot. This leads us to consider the method of constructing such bottom work, and to give some directions, from experience, of performing it in the best manner, that it shall not be subject to decay or damage for a very long course of years.

It is customary in many places, to construct the bottom work of undershot-mills of timber, a material very subject to decay in water-works, where it is sometimes wet and sometimes dry; and for this reason it is, that such work, as also

locks and sluices of timber, seldom last longer than 20 or 30 years, and in that time must be entirely new done and rebuilt; which is a heavy expence upon the owners, and much reduces the value of such estates that have a dependence upon water-works. Timber is also liable to wear in the run of water. But the circumstance of the greatest consequence is, that when the bottom work is done with timber, as it is commonly performed, the weight or pressure of the head of water is so great, especially near the bottom, that if it finds the smallest passage, it will, by its constant pressure, wash and wear away the earth at that passage and force its way under the sill (which is called blowing) till the bottom is so much torn away, that there is a necessity of taking it entirely up and rebuilding it. This happens sometimes so suddenly, that the danger is scarcely perceivable, till the blowing is past remedy. I have known several instances of this kind, and
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one in particular, where the blowing, had it been perceived in time, might have been prevented or the bottom secured, for about 40 or 50 shillings, that cost above 150l. to restore it.

This expence is frequently greater, but in none perhaps so great as in that memorable breach in the banks of the river Thames at Dagenham; where, by a neglect of repairing a sluice in time, the river broke in upon the levels of Dagenham and Havering in Essex, and washed away above 100 acres of the solid land, to the depth in some places of above 30 and some 40 feet; and cost an immense sum to stop the breach; all which might have been saved, had the bottom of this sluice been built with stone or brick, in the proper manner. But many sluices in the banks of the Thames are still built with timber; and it is not uncommon for sundry breaches to happen there, in consequence of their being so built; though none of them have been attended with so

very

very great damage and expence, as that at Dagenham. Yet, some time before that, there was one at Longreach, below Purfleet, which continued more than seven years before it was stopped.

To secure the bottom of mills, and other works in water, where that is raised and kept up above the common level, it is necessary to lay the foundation deep to prevent blowing. But in some situations the soil is springy, or a quick-sand, where it would be expensive to keep out the water, so as to lay a deep foundation; and after all might prove insecure, and not sufficient to prevent the penetration of the water under it: for the pressure of the water upon the bottom is very considerable.

As, for example, suppose the head is 6 feet high, every square foot of the bottom sustains a column of water 6 feet high, whose base being a foot square, the column is 6 cubic feet, at $62\frac{1}{2}$ pounds per cubic foot, is 375 pounds, continually pressing

passing upon every foot square of the bottom; wherein if it finds the smallest subterraneous passage, the water will force through it, with a velocity of 19.64 feet per second, which is more than sufficient to carry away the earth all round this small subterraneous passage, still making it wider, till the bottom is blown, and must be taken up.

This weight and pressure of the head-water, is only from the surface to the bottom fill of the penstock, and reaches no further, provided the ground there is a clay, or other strong close soil, through which the water cannot penetrate: but if the earth there is a sand, gravel, or porous soil, the pressure is continued through these pores, and the force of it still increases in proportion to the depth; and hence the great danger of blowing: for water presses not only downwards, but in all directions; for which reason, though the bottom and sides should be secured from leakage to the depth of a yard or more,

more, the water will notwithstanding penetrate deeper, and force its way up through the apron; or running all the way under, will force its way up at the lower end of it.

If the bottom of the thorough was not secured from the violence of the water issuing through the penstock, it would quickly carry away the earth of the thorough near the upper end of it, to a great depth, and the head-water finding little resistance, and penetrating under the fill, the bottom would be blown in a very short time: to prevent this, it is usual to cover the bottom of the thorough there, with an apron or sheeting of boards, and to drive short piles across the thorough at the lower end of the apron: this is some defence against the running-water, but it is only temporary. The continual current wears the apron in holes, and the head-water is found to force its way, not only through the apron, but frequently under the piles. And upon the whole,

whole, the bottom-work of these mills, sluices, locks, dams, and other such water-works, either from wearing by the running water, or blowing, are generally subject to decay in no long course of years.

The locks on the river Thames, are dams made across it, to pen and keep up heads of water for the mills; an opening is left in the middle of the dam about 20 feet wide, for the vessels navigated upon that river to pass up and down, and after they are passed, the opening is shut with draw-boards to keep up the head of water, about six or seven feet high. To secure the bottom of these dams, rows of piles are drove across the opening, and great quantities of large chalk-stones thrown in between the piles, sloping from the head to the bottom of the river; which prevents the water from gulling the bottom close to the head-water. But it falls upon the chalk, and runs with such rapidity, that the ground below the chalk

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is loosened and carried away, to a very considerable depth and distance, and a bank is thrown up below, by which the barges are frequently obstructed or stopped. The same thing would happen in the thoroughs of mills, if the bottoms of them near the head, were not covered and defended against the impetuosity of the water issuing through the penstock: the water would gull and drive away the earth to a great depth near the head, and then the head-water, by its weight or pressure, would soon force its way under the fill of the penstock, and blow up and destroy the bottom-work. For this reason it is absolutely necessary to secure the thorough, by aprons or some other means.

Could a head of water be kept up to the height of 6 feet, by a stone or brick-wall, laid 9 or 10 feet deep in the ground, the blowing might be prevented by such a wall, provided the earth was not carried away below the wall, by the water

running through the opening of the penstock : or it might by the same means be prevented, where the head is a great deal higher, by making the wall of a proportionable depth in the ground. But in great depths, the building of such a wall would not only be very expensive, but in bad ground often impracticable.

To give an example of this, it may be here observed, that when it was determined to build a bridge across the Thames at Westminster, different methods were proposed of laying the foundations of the piers in the bed or bottom of the river, of a sufficient depth ; whereof one was by means of batterdeaux or coffer dams ; which Mr. Labelye, the engineer, describes, and gives some reasons why that method was impracticable in laying the foundations for the piers of that bridge, as follows.

“ In building of the piers of bridges, sluices, and other works in water, engineers and architects have often recourse
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to this method, viz. to inclose the place intended for the foundation so as to keep the ambient water from coming in, that it may be drained dry, and kept so by pumping or other engines. Sometimes this inclosure is single, and sometimes double, with clay rammed between; sometimes the inclosures are made with piles only, driven close by one another; sometimes these piles are notched or dovetailed one into another; sometimes the piles are grooved, and driven at a distance, and boards let down between them. But let the inclosure or inclosures be made in any of the ways mentioned, or in any other way, the sole intent of this manner of proceeding, is only to keep the water from coming into the foundation, whenever it can be drained.

“ The first inconveniency attending this method is, that if the inclosure be not strong enough, or not sufficiently propped or braced in the inside, it will not be able to support the pressure of the

external water, (especially if it be water agitated by stormy winds) which, by breaking and bursting in, often destroys many lives, and entirely defeats the intentions of the projectors, that have not taken the necessary precautions, of which I could give a great many instances, some of which I have been an eyewitness to. But if this method had no other inconveniency, it could easily have been remedied in the execution of the intended bridge; England, and London especially, abounding with excellent artificers of all kinds. But what would have rendered it entirely useless, or ineffectual, is the nature of the ground under the bed of the river Thames; which at the place where the bridge is, is every where a gravel, covered over on the Surry side with a sort of loamy sand; all which would suffer the water to ouze up (notwithstanding the fides of the batterdeaux or coffer-dams should be perfectly tight) so fast, especially the gravel, as to put it out of the power

power of any engine or engines, to drain the batterdeaux or coffer-dam. Indeed where the ground under the foundation is a stiff clay, or an earth of a sufficient consistency to hold water, batterdeaux or coffer-dams have been used with success, though attended with an immense expence and trouble; and what I would have made use of, if I had not foreseen, that it would have been in vain to attempt in this place to come at the bottom, and much more so, to reach several feet under the bed of the river, by any such means. Those that have seen (or have been concerned in) buildings erected in water, where the ground is a gravel, or a loose clay, or a sand, well know the insuperable difficulties that would have arisen, if such coffer-dams or batterdeaux had been attempted on the Thames, over against the Woolstaple; where besides the agitation of the water, occasioned by the winds, the height of the water is perpetually increasing or decreasing, from

6 feet to about 23 feet, perpendicular height, above the surface of the bed; which two circumstances would make it difficult, and very expensive, to provide proper materials, and construct a cofferdam sufficiently strong, to resist such unequal pressures, so as to keep out the ambient water.

“As to the ouzing in of the water through the pores and interstices of the gravel, loose clay, or sand, it may easily be shewn, that if all the interstices in the bottom of the foundation, of one of the piers, taken together, amount only to a hole of 6 inches square, (which is a supposition much under the truth) and suppose the tide or height of the water above the foundation (as it is at a mean or average between the highest and lowest) about 15 feet perpendicular, they would give above 770 tons per hour; which is more than 70 men could pump out, even supposing them to act always with the same strength as they do at first, and to work day

day and night without ceasing; and more than 150 men, or 30 horses could do, working as they commonly do.

“All that I shall add to this article is, that some of the persons who proposed or espoused this method of making an inclosure round the intended pier, with dovetailed piles, and pretended to drain the water from within, might remember how fruitless was the attempt, or rather experiment, that was made of it in Hyde Park, not many years ago.”

The force of the water rising through the bed of the river appears further from the account given of it by Captain Perry, as he found it in laying down the apron of a sluice that he made at Daggenham, before he began to stop the breach there; which he relates as follows, viz.

“When I came to dig down the place for my sluice, notwithstanding that I had, (when I came within about 6 feet of low water mark) driven down large dovetail piles, on each side and

athwart the place, which I dug down for the most part upwards of 20 feet into the ground, by extraordinary engines for it, whereby to stop the course of the springs; which was done with large beams of timber, fixed across from side to side, to prevent the sliding in of the banks; yet I found the penetration of the water to have that force, underneath the dovetail piles, through the sand and bad ground below the moor-logg, that the pressure of the water at the depth which the ground was dug down, being near 22 feet difference of level upon the spring-tides, so swelled and lifted the moor-logg in the place for the sluice, that it rounded up in the middle several inches, above the level to which it was dug; and the leakage began to take such power, that I thought it not safe to open the ground any lower, and submitted to fix the foundation or apron of the said sluice to a less depth than I would willingly have fixed the same to: and consequently as I could
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not place the sluice to a greater depth, there could not, in the course of carrying up my works in the breach, be given so great an ease and vent to the water, by the way of that canal, as was necessary; the top of the apron being fixed only to within a foot of the depth of the ordinary low water mark in the Thames; which would have been of much more service and satisfaction to me, could the same have been carried lower."

He then proceeds to relate, that as he could not lay the bottom of this sluice any lower, he thought it adviseable to put in another; which, says he, "I found equally difficult in fixing down that sluice as the first; so that though I carried the foundation to a considerable depth beyond what was possible to have been done without the said drift of dovetailed piles, yet found I durst not venture the fixing of the apron of either of them below, or fully to the depth of low-water

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mark, lest I should have been overpowered by springs and leakage."

It is not commonly necessary to dig down for the foundation of mills and other works, so low as in the above instances; yet where it is so, to the depth of about 10 or 12 feet, it is found expensive to lay the bottom dry, and keep it so, till the foundation is laid, and carried up to a proper height; and several pumps are frequently necessary for that purpose, to be worked by men or horses.

One of the best sort of pumps for this use, where there is room to work it, is that known by the name of Archimedes's screw; which consists of a round shaft, with grooves cut in it, in a helical or spiral line, from one end to the other: into this groove boards are fitted and fastened in, near the whole length of the shaft, the sides of these boards are to join close to one another, and to stand at an equal height above the shaft: upon the tops of these

these boards are fastened, narrow parallel boards all round, in form of a cylinder or barrel, secured with iron hoops. This pump is to be placed not upright, but declining at an angle about 45 degrees from the perpendicular. By turning, the lower end dipped in the water, it brings the water up to the top with very little friction, whence it is to be carried off in a trough.

Sometimes there is one spiral groove cut in the shaft, to receive the upright boards, which in that case forms but one spiral thread within the barrel; and this is the most common. But I have found that two such threads, running parallel and equidistant, the length of the shaft, is better than one, and will throw out more water. But with three threads it will not discharge so much water as with one.

The largest of these pumps may be about 18 feet long. The more upright it is set, it raises the water higher, but

in a smaller quantity. Laid much inclining, it raises more water but not so high, and requires the more strength to turn it. Such a pump kept constantly going, will employ 16 horses to turn it, four at a time; and is hard work for 12 horses.

Smaller pumps of this sort are worked by men, 5 or 6 at once, and frequently changed.

But there is another method of securing such works from blowing, cheaper, more easily performed, and not less effectual than the best walls, either of stone or brick, or to any required depth. This is by piling. A line of piles, under, or just above, the still of the penstock, may be driven to such a depth, as to prevent blowing, even without an apron, and though the earth in the thorough was washed away as deep as the running-water from the penstock could remove it. So that if this one line, under or close to the fill is secured, there is no danger

RUNNING-WATER, &c. 411

of blowing. A circumstance that none of the millwrights I have conversed with, nor others of more extensive knowledge in water-works, seem to have fully considered. They lay aprons, or sheetings of boards below the fill, upon which the head of water is raised, and sometimes aprons are laid above that fill; and they drive short piles at the lower end of the apron, and sometimes also at the upper end of the sheeting above the fill; all with an intention to prevent the head-water from penetrating under it, but the line under or close to the fill, is left defenceless; and yet if the water penetrates there, all the other precautions will avail nothing.

Some have supposed that timber will decay in water, which if alternately wet and dry it certainly will. Or if laid in running-water, it will waste and wear away; not from any natural decay of the timber, or corrosive quality in water; but on account of the motion, which occasions

cations a friction and wearing of the timber by the sand and gravel mixed with the water: but to suppose that sound timber, laid at any depth in still water, will waste or decay, is a great mistake, and contrary to experience.

For it is found, that timber which has lain 50 years, or much longer, under water, is perfectly sound when taken up. And many heavy buildings in Holland and England, as London bridge, and others, built upon piles, have stood firm for ages; which is a proof that timber does not decay in water. The sense of the public, and of eminent engineers in this point, is evident from Westminster bridge, and more lately from Black Friars bridge; they being built upon gratings of fir timber, covered with fir planks.

In order to explain the method of constructing the bottom of a mill or other work in water, in such manner as will render it secure and lasting; let us suppose that the bottom work to be made, is
for

RUNNING-WATER, &c. 413

for an undershot-mill, where the head of water is penned up to the height of 6 feet, above the common surface of the river that is to drive the water-wheels of the mill: that there are three thoroughs of 4 feet wide each, and two water-wheels, to be placed in the two outside thoroughs, and the waste thorough in between them.

First, drive a row of fir piles across the stream, 6 inches thick and dovetailed, as *pp.* Pl. III. fig. 3. These piles should be driven into the bed of the river 9 or 10 feet deep at least, viz. half as deep again in the ground, as the head-water is raised above it; this upon supposition that the bed of the river, is a firm close soil, which may be known by boring. But if it is a loose earth, or quicksand, it will be advisable to drive the piles deeper, viz. not less than 12 or 14 feet deep; or, which is still a better rule, till they reach and penetrate 3 or 4 feet into good close earth. The dovetail grooves in the sides of the piles will guide them

them in driving, so that they will join close to each other throughout their whole length, and as they will be always wet, they will swell a little and continue so close, that no water can penetrate through the joints. The air will be likewise excluded from them; and therefore, if they were found at first, they will continue so: for it is the changeable temperature of the air that causes timber, that is exposed to it, to decay.

When the piles are driven to the depth intended, dig a trench close to the row of piles of 3 feet deep or more, and 2 feet wide, in which the foundation is to be laid, of a brick-wall 2 feet thick. When this wall is brought almost as high as the bed of the river; saw off the tops of the piles in a streight line, very true and even, as low as the bed or bottom of the river; then build the wall up as high as the tops of the piles, after which the wall is to be extended in breadth over them from *w* to *p*, and carried up to the proposed height, battering

battering on the lower side *w, w*, to 18 inches or two bricks length. This wall, when carried up to the proper height, is to be one side of the mill.

If the ground is bad, upon which the wall is to be built, lay 2 long four-inch oak or fir planks at bottom, each 14 or 15 inches broad, and build the wall upon them, which will prevent the wall from settling; but if there is a quicksand at bottom, or so springy that a trench cannot be dug for a foundation, it must either be closed piled all over, or double rows of piles driven across the trench at small distances from each other, and arches turned upon them, to support the wall. Thick planks should be laid upon the tops of the piles, and the wall built upon them.

The brick-work of the foundation should be laid in tarris mortar, but no mortar of any sort laid next the sides of the dovetail piles, nor upon the tops of them; for the weight of the brick-work

built

built upon them, will make it bed close to them, provided they have been sawed off level, and as true and even as they ought to be. The bricks for this use should be of the best sort, and very well burnt. The bottom-work being constructed in this manner, the materials will continue perfectly sound, and no water can ever penetrate through or under it.

The brick-walls of the thoroughs *abcd*, should be carried up together with the cross or breast-wall *w, w*; for the middle walls *b, c*, 14 inches thickness may be sufficient; but the two outside walls *a, d*, should be at least 2 bricks and a half, or 22 inches thick, as they will serve as abutments to the breast-wall, and help to support it against the weight or pressure of the head-water.

The breast-wall, as high as the water rises, and walls of the thoroughs, should be laid in tarris-mortar, but it is not necessary that they should be built wholly with that mortar. It will be sufficient if
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the bricks are laid in tarris, 3 or 4 inches into the walls next to the water, and the rest with other good mortar. The tarris is peculiarly adapted to brick or stonework built in water. The thoroughgs of mills built with this mortar are almost immediately fit for use. The violent current of the water is not able to wash it out of the joints of the work, though let in upon it but a few hours after it is built; but on the contrary it swells or grows out of the joints, and hardens to such a degree, that no run of water affects it.

The bottom of the thoroughgs should be paved with bricks set on edge, or two courses of them laid flat, and laid wholly in tarris-mortar, from the breast-wall to to the length of some yards below the wheels. Some persons may be apt to think that this method of constructing the bottom is in a great measure a needless expence; but let such be assured, that too much precaution can scarce be used, to guard against the force and pe-

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netration of water, raised to any considerable height above its common level; and it is certain from experience, that a great deal more is saved in the end, by bestowing a little more expence to construct such works at first effectually; than to perform them superficially, and be obliged to rebuild them in a few years, from a decay of the materials; or, which not unfrequently happens, by the water forcing a passage underneath, and blowing up the work.

The construction with stone differs in nothing material from brick; and either of them may be used with success, that is cheapest, or can be most conveniently obtained.

The dovetail piling and breast-wall are to be continued in length, through the banks of the river on each side, if the length of the mill extends so far: but if it does not, the brick-wall may be finished at each end of the mill with strong quoins of brick-work, and the dovetail

piling

piling continued through the banks, or three or four yards into them, to prevent the water penetrating round the ends of the piling; observing not to cut the heads of the piles that run into the banks so low as those joining to the wall; but to leave them as high as the top of the banks, or to such a depth only below the surface of the ground, that they may remain always wet, and by that means be covered from the air, and their tops secured from decaying.

It is usual to continue the walls or wharfing of the head-word with wings, carried up a little higher, and nearly at right angles with the breast-work. These wings are a sort of wharfing next to the water, and intended to prevent the water getting round behind the breast-work: but in constructing these wings, great care should be taken to make them very close and impervious to the head-water, as deep as the breast-work; and that they should join perfectly close to the breast-work, so

that no water can get in between them. The wings secure the banks from mouldring down, as far as they go, but are not necessary to prevent the water getting round; for the dovetailed piles, if continued far enough into the banks, are an effectual security against the penetration of the water there, without wings.

Though this method may appear expensive, it is not so much more than the common constructions, as it may seem to be at first sight. For it is customary to lay an apron or sheeting of boards, sometimes one above the breast-wall, and always one below it in each thorough, to prevent the earth there being carried away, by the force of the water issuing through the penstocks, which otherwise it would be to a great depth, and occasion the blowing up of the bottom in a short time. And under each of these aprons there must be frames of timber, to which the aprons are fastened. If to
this

this is added the piling to each apron, it will appear that the difference of the expence is not very great, for neither aprons, timber-frames, nor the common piling, is necessary in the above method of constructing the bottom-work.

Where there is a plenty of stone the bottom-work may be done at a small expence, and very substantially, and the bottom of the thoroughs being done with large blocks, they will lie very firmly, and not liable to be displaced by the current of water, which having the greatest velocity next the penstock, the bottom pavement should be laid deepest there, and may be of a less depth gradually, from thence to the tail or further end of the thorough. In this way of constructing it, and laying the work in tarris-mortar, the bottom will be perfectly secure, and in no danger of blowing at bottom, nor of displacing any of the pavement at top.

In many places where stone cannot be got at a moderate expence, chalk may: and chalk is easily cut into square blocks, before it is thoroughly dry, which it should be before it is made use of in such work: and when it is so, and laid in tarris-mortar, will remain firm, and not subject to decay under water, nor to wear by the water running upon it; but will contract a kind of moss or thin crust upon it, that will defend it from the water.

There are different sorts of chalk, or different degrees of hardness: soft soapy chalk is not proper for this purpose; but in most places where chalk is found, it is of a considerable depth, and lies in strata or beds like free-stone, and may be raised in large blocks, which harden when exposed for some time to the air and sun in summer; but if dug and exposed to the weather and frost in winter, being then wet or moist, will be apt to crack and break in pieces: for which

reason chalk that is intended for such bottom-work, should be raised in the beginning of summer in blocks, and laid to dry and harden in the sun and air, and then it will be in fit order for this purpose.

In such places where neither good bricks, stone, nor chalk are to be had at a moderate price, there is another method of constructing the bottom-work of mills, and other machines worked by water, viz. by a kind of chest-work, resembling the ancient method of constructing the walls of cities, castles, and other such buildings; viz. making a chest with a double row of planks, placed parallel, and as wide apart, as the intended thickness of the wall. Stones and flints of different sizes were thrown into this chest till full, and then a strong liquid mortar was poured into it, which filled the cavities between the stones, and cemented them together into one body, strong enough to support the rest of

the wall, raised by degrees in the same manner; which in time were consolidated, as we now see the remains of many of them, as if a whole wall consisted of one solid stone.

Similar to this, the bottom work may be constructed with flints, or common stones, and tarris-mortar: as suppose that a double row of dovetailed piles are driven, parallel to one another, and as far or a little farther asunder than the proposed thickness of the breast-wall; the space between the piles is to be partly filled with the stones, and then tarris-mortar as high as the stones, to fill up the cavities: put in more stones, and then tarris-mortar, till the work is raised to the intended height. There is an advantage in this kind of work, which could not be had in the ancient way of building walls. For they required time to dry and harden the work; but the tarris-mortar sets and hardens quickly, if any water is let into it: for which
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reason a solid substantial wall for a foundation, may in this manner be made in a short time. The heads of the piles being cut off level with the bed of the river, and planked at top, a wall may be raised upon this, in the same manner as upon any other foundation.

The locks of the Bath navigation are built with stone, and the engineer who constructed one of them, told me some years ago, that they had a strong lime whereof the mortar was made, which was got from a kind of hard stone in that neighbourhood. This lock was of more difficult construction than the others, and the river being confined there by rising ground on both sides, was subject to sudden floods after hasty rains. This happened once when his men were in full work, and the torrent was so high and impetuous, that the men were obliged to leave their work of a sudden. As the floods there rise quick, and are very rapid, they are of short continuance,

and next day, or day following, the men returned to their work, when they found that part of the materials and most of their tools were forced into the river by the strong current, and carried to some distance below: but what was most remarkable, the mortar they had made was hardened to the consistence of stone; and their trowels that happened to be left in the mortar, could not be got out without breaking the mortar with hammers.

There is little reason to doubt, that stone of the like kind may be found in other places, if diligently sought after; and a lime may be got from it, that with good sharp sand, washed, would answer the purpose of tarris-mortar; and not only at a cheaper rate, but in some respects preferable to the tarris; which though it is excellent for water-works, is not so proper as other good mortar for common building, but the above Bath-mortar, is fit for all buildings in or out of water.

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The water-wheels of ground-shot mills erected upon rivers, are not usually worked by the water of the main river; but, as in the Thames where locks are made, part of the water is diverted out of the river a little above the lock into another channel, and upon this the mill is erected.

Where there is a conveniency of diverting part of a river in this manner to a good distance below, as suppose a mile; in that distance the descent may be such, that a very good head of water may be obtained to work a mill erected there. As suppose the difference of the level from the river to the mill to be only 8 feet, a head of water of that height would drive one or more breastshot-wheels, and do a great deal of work; and such a mill may be built to stand clear of back-water; which is a great obstruction to breastshot-wheels.

In making a channel to conduct the water, it is done at the least expence upon

upon the side of a sloping ground, as in that case there is only one bank to be made on the lower side, the natural ground on the upper side making an excellent bank, without any expence at first or afterwards, as it will want no repairing; and the earth dug out of the canal will serve to make the bank on the lower side. If the soil for that purpose happens to be a gravel, the water in the canal will penetrate through such a bank, and cause a considerable leakage: for which reason it will be necessary to make a small ditch near, and parallel to, the bottom of the bank, to receive and carry off the leakage. Water contains in it a slimey substance, which will insinuate into the cavities of the gravel, and cement it so closely, that after some time, the banks of gravel become the strongest and closest of any, as experience shews.

A canal of about 8 feet wide and 2 and a half feet deep, will supply the mill with 20 cubic feet of water per second, running

running at the rate of 1 foot per second; and a canal of these dimensions may be dug, and the lower bank raised with the earth dug out, for about 10 pence for every yard in length, and in many places for much less; especially if the earth of the canal is first loosened with a plough. But at 10 pence per yard the expence of making such a canal of a mile in length, will amount to about 200 l. This, by some persons may be supposed a low estimate; and allowances are to be made, if the ground to be dug was rocky, that required to be blasted; or a very hard gravel that must be loosened with pick-axes. But for common earth, that may be easily dug with a spade, this estimate is too high.

The late Mr. Wood of Bath, agreed to cut one of the canals of the Bath navigation, through a strong clayey soil, at the rate of 2 $\frac{1}{2}$ d. per cubic yard; but when he came to treat with labourers there to perform it, they demanded as much

much or more, than he was to receive for doing it: upon which he brought a number of labourers from London, who performed the work, and threw the earth upon the banks on each side, for three half-pence per cubic yard, and at that rate earned good wages. The cutting of the above canal is reckoned at near that price, though not worth so much; as this is not so deep nor more than a third part of the breadth of the Bath canal; and consequently not near so much labour to throw out the earth.

The depth of 2 feet and a half, may be sufficient to supply the mill, but if the river will not at that depth furnish a constant water, it will be proper to cut the canal deeper, that the mill may have water enough at all times; and if it draws then too much from the river, the canal may be made narrower, but of the necessary depth, and not deeper than is necessary, as that would be an abatement of

the head-water at the mill, which should be raised as high as can conveniently be done. A mill erected upon this plan, may be so constructed, as to be entirely free from back-water, and be no way subject to floods, or want of water.

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DISSEMINATIONS



RURAL SUBJECTS

Wm. G. POTTING